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MOBILE PLANT AND WATER TREATMENT TESTING AT THE CROWS NEST RESOURCES LTD. LINE CREEK WASHERY DURING 1983

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by

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ABSTRACT

Field tests designed to complete initial shake-down of the water treatment mobile plant were carried out at the Crows Nest Resources Ltd. Line Creek washery during the month of July, 1983.

Tests for evaluation of cationic and anionic reagents for use in the washery tailings thickener helped identify a number of areas of needed improvement in mechanical, operational and experimental aspects that would enhance the R & D potential of the mobile plant. While the evaluation tests did indicate that significant technical and economic improvement in thickener operations could be achieved with reagents other than those being used, the small number of observations and lack of optimization for each reagent did not enable rigorous comparisons between them.

Recommendations include the installation of control instrumentation and provision for more flexibility in adjustments of the feed and underflow pumps to ensure equivalence for scale-up. The experimental design and analytical aspects of the work need attention to ensure the relevance and reliability of results for purposes of optimization and parameter selection and for development of control strategies. As topics for R & D, investigation of the reliability of the wedge and of the relationship between reagent characteristics and performance emerged as being of immediate importance and interest.

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INTRODUCTION

Under present economic conditions, the Canadian coal industry is faced with having to achieve significant reduction in production costs to retain its competitiveness in the marketplace. During 1983, the costs associated with treatment of process waters and tailings were conservatively estimated at approximately $2.6M for the industry at large. With reagents alone accounting for $1.5M of this total (7-11 cents per tonne of clean coal), there is the real likelihood that economies could be realized in most washeries through optimization of the processes and through the use of more cost-effective reagents.

While it may be that the work needed for process optimization and/or selection of reagents would best be done by testing in the washery during normal operation, there are obvious practical difficulties because of scale and because of the risks of creating conditions that could adversely affect product quality and of generally disrupting operations. The Edmonton Coal Research Laboratory mobile plant was conceived specifically to avoid such problems through its capability for experimentation using a sidestream of the effluent. However, because the mobile plant tests are usually conducted within a relatively narrow time frame and range of variation in feed characteristics or other conditions, scale-up requires a significant degree of extrapolation and special care in the design of experiments and conduct of the work to ensure the highest return of useful and reliable information.

Arrangements were made to conduct field tests with the CANMET Water Treatment mobile plant at the Crows Nest Resources Ltd. Line Creek washery in southeastern B.C. during the month of July, 1983. One of the principal objectives was to complete the mechanical shake-down of the mobile plant and to provide for the continuing development of appropriate experimental procedures. To meet this objective, the opportunity to address an existing washery water treatment problem was needed. Such a problem was presented by the operation at Line Creek where to obtain a minimum wedge clarity of 30, reagent consumption was approximately 12-14 times target dosages of 35 g/t cationic and 30 g/t anionic ($0.15 per tonne of tailings). Moreover, the solids concentration in the thickener underflow was less than optimum at these high dosages for dewatering in a belt filter press.

The clarification and thickening potential of one anionic reagent and of four cationic-anionic reagent combinations from five different manufacturers were tested. The combinations included the one used in the washery where the two reagents were added at a fixed ratio in the order cationic-anionic. Comparison of results achieved in the mobile plant with those occurring in the washery was enabled by simultaneous monitoring of the washery thickener. Time-related trends during the tests were determined from overflow and underflow samples taken at regular intervals. These samples along with solids concentration profiles determined at the conclusion of each test assisted in the calculation of material balances. Test data from the monitoring and interval samples and for thickener profiles and feed size distributions are given in four Appendices. Results for each set of reagents are summarized in the body of the report. The discussion is aimed at rationalizing their technical and economic performance and at gaining some insights into operating relationships for use in planning future testing and R & D.

EXPERIMENTAL PROCEDURE

As indicated in Fig. 1, feed to the mobile plant was a sidestream of the primary feed to the washery thickener. This sidestream was pumped to a holding tank within the washery and from there to a 45 m^3 feed tank in the mobile plant. Agitation in this feed tank was maintained with a mechanical stirrer. Feeding to the Ecodyne 8-ft (2.4 m) diameter x 6-ft (1.8) high Rota-Rake test thickener was with a 50 igpm (3.8 L/s) centrifugal slurry pump. The 15 igpm (1.1 L/s) Moyno underflow pump was operated intermittently during some of the initial tests but continuously in the remainder. Flocculant was prepared as a concentrated solution and mixed for approximately 20 minutes before transferring to a dilution tank. The short dissolution times for powder flocculants was made possible through the use of a two-stage atomizer that produces rapid dispersion and wetting of the particles. When using two reagents, addition was in-line ahead of the thickener for the cationic and in the thickener feedwell for the anionic. For the tests involving the anionic CFA-50 by itself, addition was in-line.

Including preparations, the duration of each test was between 2 and 2.5 hours allowing a maximum of 3 tests per working day.

After filling and prior to beginning flocculant addition, pumping to the thickener was continued for about 30 minutes to establish equilibrium conditions. Immediately following the start of flocculant addition, overflow and underflow samples were collected at 5 minute intervals over the 60 minute test period. The overflow samples were checked immediately for clarity using an Allied Colloids wedge and the underflow samples for solids concentration using a Marcy scale. At the conclusion of each test, 1 litre analytical samples were collected simultaneously from the feed, overflow and underflow. Samples representing the solids concentration profile within the thickener were obtained from 11 sampling points spaced at 4-inch intervals down the side of the thickener wall. Samples of the washery thickener feed, overflow and underflow were also collected at this time. All samples were analyzed for solids content. Screen analysis was performed only on the feed and the ash contents generally determined only on the feed and underflow products where sufficient solids were present.

A single test (F) was performed without reagent. For all tests with reagents, low (L), medium (M) and high (H) dosage levels were used. These levels were nominally 15, 30, and 60 g/t for the cationic and 17.5, 35 and 70 g/t for the anionic i.e., at a constant cationic : anionic ratio of ≈0.86:1, approximately the same as used in the washery (C.85 - 0.90:1). For those reagents used in the washery (Alchem), a replicate test at dosage level L and one using the washery dosage level (P) of 420 g/t each of cationic and anionic was also performed. Reagent dosage was adjusted on the basis of an estimate of the feed solids content for the first test run of a particular set of reagents on a given day. As a result of subsequent corrections based on the determined solids contents of the feed samples, some departures will be noted from the nominal target dosages.

ANALYTICAL METHODS

Total solids contents of the feed and overflow were determined in duplicate by evaporating sample aliquots to dryness at 105-115°C. The aliquots were obtained by pipetting from the sample containers after thorough mixing. No correction was made for dissolved solids. For the underflow samples moisture was determined by evaporation after decantation.

Ash contents were basically determined using ASTM standard procedures. Screen analyses were performed on a cascade-type wet-sieving apparatus using 30, 60, 100, 140, 200 and 325 mesh US Standard sieves.

MATERIAL BALANCES

The accounting for material balances was complicated by the fact that full steady-state conditions were not generally established within the 1-hour test period. In addition, overflow ash contents were not available and those for the underflow products are considered to be of questionable accuracy. This arises from the fact that the differences between the feed and underflow ash contents could not be reconciled and that the ratio between the two decreased systematically as the feed ash increased. It appeared likely that either fine high-ash solids were lost through the decantation procedure or that a correction for residual moisture after evaporation would have been required.

The material balances were determined through calculation of the overflow solids contents based on the solids concentration profiles at the conclusion of the tests and the determined feed solids concentrations. It was assumed that the solids residing in the zone above the feed entry level after 1 hour would constitute a reasonable approximation to the steady-state condition in that zone. All solids below this level, as determined by difference from the known feed throughput, were then taken to represent the underflow at steady-state. Good agreement was obtained between these results and those calculated on the basis of the 1-hour average underflow solids content from the 5-minute interval samples.

FEED CHARACTERISTICS

During the tests, the solids content of the sidestream of the washery flotation tailings thickener feed averaged 2.17%, equivalent to an average solids throughput of 0.33 stph or a loading of 13.16 $lb/ft^2/h$ to the mobile plant test thickener. On average, the solids contained 25.8 ±4.2% ash and 49 ±7% fines at minus 44 μm (325 mesh).

The solids and ash contents and the size distribution data showed no statistically significant differences between the two washery thickener feed

samples (locations 1 and 2) and the sidestream to the mobile plant. For purposes of the tests, this tailings sidestream can therefore be considered identical to the washery stream(s). The plots of the fines, ash and solids contents show that between July 16 and 25, 1983, the test-to-test and/or day-to-day variations in the feed would have exceeded any that could be attributed to sampling and analytical error or to systematic differences between sampling locations (Table 1 and Fig. 2; Appendix A).

Although confirmation is needed, the screen analyses suggested that the tailings could be characterized by a bimodal distribution showing a major mode at ≈120 μm and a minor one at ≈2 μm. These could indicate that while the tailings consisted primarily of a relatively coarse coaly fraction, a much smaller quantity of clay was also present (Fig. 3). On the overall, a decrease in the feed ash content appeared to accompany an increase in the percentage of minus 44 μm fines. This was not always the case for the individual feeds, however, and further investigation would be needed to determine whether there were changes in the seams being washed or in the source of the tailings during the 2 to 3 week testing period.

Table 1 - Average screen analyses of thickener feed samples from washery locations 1 and 2 and the mobile plant

Particle size (μm)	Location 1		Location 2		Mobile Plant	
	Mean	s.d.	Mean	s.d.	Mean	s.d.
+ 595	0.37	0.61	0.13	0.35	0.17	0.39
595 - 250	2.13	0.96	1.63	1.20	2.23	0.61
250 - 149	11.40	3.82	11.06	4.07	12.21	3.60
149 - 105	11.92	2.78	12.28	3.06	12.61	2.55
105 - 74	11.23	2.30	11.15	1.89	11.41	1.96
74 - 44	12.55	4.55	12.18	4.84	12.05	3.29
- 44	50.40	7.66	51.57	9.08	49.32	7.06
Total	100.00	-	100.00	-	100 00	-

There was considerable range in the variation of feed solids, ash and fines contents both between and within tests. For example, the solids throughputs during the tests with Alchem products (B) were below the overall average of the tests with all other reagents and likewise, the feed ash contents during the tests with Stockhausen products (E) were above average while the fines contents during the tests with the Crosfloc anionic reagent (A) were far above average (Fig. 4).

MOBILE PLANT TEST RESULTS

In the following tables, wedge clarity is reported as both the overall test average based on all the samples taken at intervals during the tests and as the readings on the initial and final samples. The overflow solids content in ppm represents the total solids present above the feed entry as determined from the solids concentration profiles at the conclusion of the tests and comprising the region down to a depth of 61 cm below the surface (spigots 1-6). The underflow solids contents represent the 1-hour average concentrations calculated from the interval samples taken every five minutes during the tests. The feed and underflow ash contents were determined on the final 1-litre samples. The solids recovery in thickener underflow was calculated by difference from the feed and overflow tonnages based on solids contents and flowrates and the water recovery in overflow by difference from the feed and underflow water flowrates.

Beginning with the test without flocculant addition, results relating to the overflow and underflow products for each series of tests with reagent will be briefly discussed. Pertinent information based on the solids concentration profiles is included. Unless otherwise noted, underflow product was withdrawn continuously at the rate of 15 igpm during the course of the tests.

NO FLOCCULANT

The feed contained 2.47% solids (0.38 stph) with 31.3% ash and 55.3% minus 44 micron fines. Operation without reagent gave total solids contents of 0.95% in the overflow and 3.9% in the underflow. The quantity of solids in the overflow corresponded to a solids recovery in the underflow of only 73.4%. The water recovery in the overflow of 70.3% very nearly equals the difference accounted for by the 15 igpm underflow withdrawal rate relative to the 50 igpm feed flowrate and is consistent with the absence of true thickening during the course of the test. From the solids recovery and ash content of 22.25% in the underflow, the overflow ash content could be estimated at 56.3% by difference with the feed. However, this value is at considerable variance with the total of 24.2% determined from the spigot samples and appears to support suspicions regarding the accuracy of the underflow ash determinations.

Solids Concentration Profile

The profile shows the presence of a significant concentration of solids in the zone above the feed entry level and a rapid increase in concentration with increasing depth in the middle zone between the feed entry at 61 cm and the top of the rake at approximately 112 cm (Fig. 5). The fact that 40% of all the solids in the thickener were located in this zone compared to 27% and 33% in the overlying and underlying zones respectively can be interpreted as indicating the existence of a critical concentration. Thus, at a throughput of 14.98 $lb/ft^2/h$, the thickener would have been overloaded and in the process of filling up.

Ash contents of solids in the various layers of the thickener showed that with increasing depth, the cumulative ash decreased from 27.25% at a depth of 10 cm to a minimum of 22.5% at 91 cm before increasing to approximately 25% at levels between 102 and 112 cm below the surface.

CROSFLOC CFA-50

The anionic Crosfloc CFA-50 from Hart Chemicals is a high molecular weight partially hydrolyzed polyacrylamide (PAM) powder flocculant. It was added in-line as a dilute solution ahead of the thickener at dosages in the range of 17.5 to 70.0 g/t. The feeds contained between 1.06 and 1.59% solids (0.16 - 0.24 stph) with 22.4 to 27.2% ash and 57.2 to 64.9% minus 44 micron fines. The underflow pump was operated intermittently during all the tests.

Overflow

With increasing dosage, the overflow solids contents decreased from 110 to 41 ppm with corresponding solids recoveries in the underflow increasing from 99.4 to 99.8%. These results are not consistent with the final wedge clarities of only 13-18 which represent minimal improvement over the initial clarities of 10-11. The highest wedge reading was obtained with the dosage of 50.9 g/t coincidentally with the lowest solids feed rate in Test M (Table 2).

The equilibrium between incoming feeds and the factors determining wedge clarity was established relatively early on and maintained over the entire 60-minute period at all three dosage levels (Fig. 6a). It appears

that little or no change in the wedge readings would be expected with time given the same feeds and test conditions.

Table 2 - Mobile plant results for Crosfloc CFA 50 (flocculant A)

	Test		
	L	M	H
Date	08/07/83	08/07/83	09/07/83
Time	1420	1600	1330
Temperature (°C)	26	26	26
Cationic (g/t)	-	-	-
Anionic (g/t)	17.5	50.9	70.0
Reagent cost ($/t)*	0.052	0.153	0.210
Feed			
Solids content (%)	1.54	1.06	1.59
loading(lb/ft²/h)	9.30	6.39	9.61
rate (tph)	0.23	0.16	0.24
Ash content (%)	22.37	24.26	27.25
Minus 44μm (%)	64.91	59.74	57.15
Overflow			
Wedge clarity (initial)	11	11	10
(average)	12	16	13
(final)	13	18	15
Solids content (ppm)	110	41	41
Water recovery (%)	91.4	88.9	84.5
Underflow			
Solids content (%)	20.11	16.50	17.90
Ash content (%)	19.77	21.33	23.23
Solids recovery (%)	99.4	99.7	99.8
Solids distribution (%)			
Upper zone (<61 cm)	0.65	0.34	0.22
Middle zone (61-112 cm)	1.03	0.24	1.33
Lower zone (>112 cm)	98.32	99.40	98.45

*Dry tailings basis

Underflow

With increasing dosage and using intermittent withdrawal, the average underflow solids concentrations decreased in the range of 20.1 to 16.5% with the minimum coinciding with the minimum solids throughput in Test M. During the periods of no pumping, maximum concentrations in the range of 35 to 45% by weight were attained, with the highest values obtained with the highest reagent addition. At all three dosage levels, the rate of solids withdrawal during pump operation exceeded the rate of sedimentation and/or compaction of solids during the periods of non-operation. However, the differences between these rates dropped as the dosage increased, consistent with an increase in settling velocity (Fig. 6b). Average water contents of

the underflows ranged between 794 and 1012 gallons per ton of dry solids. While a decrease in water recovery in the overflow of from 91.4 to 84.5% accompanied the increase in dosage, the indication was that this resulted primarily from the concurrent increase in pumping frequency and consequently in the average underflow pumping rate (from 5.0 to 8.7 igpm) from Test L to Test H.

Solids Concentration Profile

The profiles show no evidence of an upper controlling concentration zone nor of a critical concentration, indicating that at solids loadings of 6.39 to 9.61 lb/ft^2/h, the thickener was operating below full capacity. Between 0.2 and 0.6% of the solids in the thickener were located in the upper zone and between 0.2 and 1.3% in the middle (Table 2). While the relative quantity in the upper zone decreased with increasing reagent dosage, it was more strongly influenced by the feed fines content. Direct proportionality between the two suggests that the fines content was likely the principal factor controlling effectiveness of solids removal at a given dosage. The percentage of the solids in the middle zone was directly related to the feed solids content, undoubtedly reflecting the effects of feed entry into the zone. Concentration effects with resulting increase in hindered settling could explain a decrease in the proportions in the lower zone with increasing solids throughput.

ALCHEM 8852 + 8C26

The Alchem 8852 (cationic) and 8C26 (anionic) liquid reagents were those in use in the Line Creek washery at the time of testing. Little is known of the chemical nature of these reagents except that the cationic is said to be of medium molecular weight and that the anionic contains a medium molecular weight PAM of medium to high charge. The tests included a replication at low dosage level (L_2) and one using the washery dosage (P). Low feed tank levels were observed at the 40-minute mark during Test M and at the 20-minute mark during Test H. The cationic was added at rates between 9.5 and 420 g/t and the anionic at between 11.1 and 420 g/t. The feeds contained 1.27 to 2.82% solids (0.19 - 0.43 stph) with 21.1 to 27.5% ash and 43.2 to 56.4% minus 44 μm fines. During the course of Test M,

clarity in the washery was measured at 31-33. Underflow was withdrawn intermittently during Test L_1.

Overflow

With increasing reagent dosage, the overflow solids contents decreased from 1202 to 174-208 ppm with corresponding solids recoveries in the underflow increasing from 96.9 to 98.9-99.5%. These results were not entirely consistent with the final wedge clarities of 12-46 which show that noticeable improvement from the initial wedge readings of 7-11 was only accomplished at the very high washery dosage of 420 g/t each of cationic and anionic (Test P). In terms of solids ppm and recovery, the results for this test were surpassed by those achieved in Test H at a substantially lower dosage. On the basis of 174 ppm solids in the overflow and the recovery of 99.51% achieved in Test H (wedge clarity = 13) as compared to 208 ppm and a recovery of 98.9% achieved in Test P (wedge clarity = 46), much closer agreement between the wedge readings would have been expected (Table 3). Although dosage appeared to be the only factor controlling wedge clarity, neither it nor any of the other measured factors could adequately explain the variation in the overflow solids content between tests. Because of the limited number of observations, it was not possible to determine which combination(s) of variables and/or interactions were operative.

For dosage levels L_1 to H inclusive, equilibrium between the incoming feeds and the factors determining wedge clarity was established relatively early on and was generally maintained over the entire 60-minute period at all dosage levels (Fig. 7a). Little or no change in the wedge clarity would, therefore, be expected with time given the same feeds and test conditions. At the washery dosage (Test P), wedge clarity began improving immediately upon the start of reagent addition, rising to the maximum reading of 46 within approximately 35 minutes.

Underflow

With intermittent underflow withdrawal during Test L_1, the solids concentration reached a maximum of 45% at the 30-minute mark and averaged 19.90% over the 1-hour test period. As in the tests with Crosfloc CFA 50, the rate of solids withdrawal during pump operation exceeded the rate of

Table 3 - Mobile plant test results for Alchem 8852 and 8C26 (flocculant combination B)

	Test				
	L_1	L_2	M	H	P
Date	16/07/83	17/07/83	17/07/83	17/07/83	22/07/83
Time	1625	1750	1145	1445	1255
Temperature (°C)	20	20	20	22	21
Cationic (g/t)	15.0	9.5	30.0	42.5	420.0
Anionic (g/t)	17.5	11.1	35.0	49.5	420.0
Reagent cost ($/t)*	0.077	0.049	0.156	0.221	1.970
Feed					
Solids content (%)	2.82	2.70	1.71	2.41	1.27
loading (lb/ft²/h)	17.12	16.37	10.34	14.61	7.66
rate (tph)	0.43	0.41	0.26	0.37	0.19
Ash content (%)	25.21	21.24	27.51	26.35	21.05
Minus 44 μm (%)	47.14	46.32	50.68	43.21	56.43
Overflow					
Wedge clarity (initial)	11	7	10	9	10
(average)	13	12	14	11	33
(final)	13	13	12	13	46
Solids content (ppm)	419	1202	641	174	208
Water recovery (%)	84.7	71.2	73.3	71.6	71.4
Underflow					
Solids content (%)	19.90	9.56	8.23	11.67	9.38
Ash content (%)	23.25	20.25	24.76	23.55	20.25
Solids recovery (%)	98.8	96.9	97.3	99.5	98.9
Solids distribution (%)					
Upper zone (<61 cm)	1.24	3.08	2.71	0.49	1.15
Middle zone (61-112 cm)	2.58	11.55	5.50	3.56	3.55
Lower zone (>112 cm)	96.18	85.37	91.79	95.95	95.30

*Dry tailings basis

sedimentation and/or compaction of solids during the periods of non-operation (Fig. 7b). With continuous underflow withdrawal during the four remaining tests, the average underflow solids concentrations varied in the range of 8.2-11.7% and tended to increase with increase in dosage but to decrease as the percentage of fines in the feed increased. Average water contents of the underflow products ranged between 805 and 2230 gallons of water per ton of dry solids. The driest product was obtained with intermittent pumping in Test L_1 and the wettest with continuous pumping in Tests M and P for feeds containing the highest percentages of fines. The effect of change in pumping regime is evident from the decrease in water recovery in the overflow from 84.7% in Test L_1 to 71 - 73% for all other tests (Table 3).

Solids Concentration Profile

The profiles show no evidence of an upper controlling concentration zone nor of a critical concentration indicating that, at solids loadings of 7.66 - 17.12 lb/ft²/h, the thickener was operating below full capacity. Between 0.5 and 3.1% of the solids in the thickener were located in the upper zone above the feed entry and between 2.6 and 11.6% in the middle (Table 3). Although the relative percentages in the upper and middle zones tended to decrease with increasing dosage, the relationship is poor and other factors which remain unidentified appear to have had a bearing on the process. Precisely the same problem of lack of definitive evidence regarding any of the known factors arises for explaining variation in the solids distributions in the lower zone.

CYANAMID SUPERFLOC 355C + A130

Cyanamid reagent Superfloc 355C is a very high charge low molecular weight liquid cationic; Superfloc A130 is a high molecular weight high charge anionic powder PAM. Both were added as dilute solutions in the dosage ranges of 15.2 to 60 g/t cationic and 17.7 to 70.0 g/t anionic. Low level in the feed tank occurred 30 minutes after the start of Test L. The feeds contained 2.44 to 2.76% solids (0.37 - 0.42 stph) with 19.3 to 27.3% ash and 42.4 to 42.6% minus 44 μm fines. Wedge readings in the washery were in the range of 40 to 43 during the tests.

Overflow

With increasing reagent dosage, the overflow solids contents increased from 230 to 365 ppm passing through a maximum of 634 at the intermediate dosage level (M) with corresponding solids recoveries in the underflow decreasing from 99.4 to 98.4-98.9%. These results correlate poorly with the wedge readings of 17 to 46 which would reflect a decrease in solids with increasing dosage. These wedge readings constitute noticeable improvement at the low and medium dosages and substantial improvement at high dosage over the initial readings of 8-12 (Table 4). The proportionally large increase in clarity achieved between dosage levels M and H appears to be in part attributable to a correspondingly lower solids throughput during Test H. Although the variation in feed fines content between the three tests appears insignificant, no other factor correlated even remotely as

well with the overflow solids content. On the other hand, discrepancies between the fines contents of mobile plant and washery feeds could cast considerable doubt on the validity of the relationship (Table A-3).

Table 4 - Mobile plant results for Cyanamid Superfloc 355C + A130 (flocculant combination C)

	Test		
	L	M	H
Date	23/07/83	23/07/83	22/07/83
Time	1410	1100	1730
Temperature (°C)	20	20	22
Cationic (g/t)	15.2	30.0	60.0
Anionic (g/t)	17.7	35.0	70.0
Reagent cost ($/t)*	0.089	0.176	0.352
Feed			
Solids content (%)	2.73	2.76	2.44
loading (lb/ft²/h)	16.57	16.75	14.78
rate (tph)	0.42	0.42	0.37
Ash content (%)	27.33	24.25	19.33
Minus 44 μm (%)	42.43	42.62	42.59
Overflow			
Wedge clarity (initial)	8	9	12
(average)	14	15	38
(final)	17	18	46
Solids content (ppm)	230	634	365
Water recovery (%)	72.8	72.6	72.1
Underflow			
Solids content (%)	18.19	17.11	13.81
Ash content (%)	24.25	22.12	19.77
Solids recovery (%)	99.4	98.4	98.9
Solids distribution (%)			
Upper zone (<61 cm)	0.60	1.63	1.06
Middle zone (61-112 cm)	2.44	2.03	2.20
Lower zone (>112 cm)	96.96	96.34	96.74

*Dry tailings basis

For the tests at dosage levels L and M, equilibrium between the incoming feeds and the factors determining wedge clarity does not appear to have been established within the 60-minute test period. Some improvement in clarity might, therefore, be expected with time given the same feeds and test conditions. At the high dosage level, rapid improvement in wedge clarity began 5 minutes from the start of reagent addition, rising to the maximum reading of 46 approximately 20 minutes later (Fig. 8a).

Underflow

With increasing dosage, the average underflow solids contents decreased from 18.2 to 13.8% by weight with average water contents increasing in the range of 899 to 1248 gallons of water per ton of dry solids. The increase in product water content was reflected in a correspondingly small decrease in water recovery in the overflow of less than 1% from 72.8 to 72.1%.

Solids Concentration Profile

The profiles show no evidence of an upper controlling concentration zone nor of a critical concentration indicating that, at solids loadings of 14.8 to 16.8 $lb/ft^2/h$, the thickener was operating below full capacity. Between 0.6 and 1.6% of the solids in the thickener were located in the upper zone and between 2.0 and 2.4% in the middle zone (Table 4). The relative quantities of solids in all three zones correlated strongly with the feed fines content, the dosage apparently having had little or no direct influence on the distributions. Whereas direct proportionality existed between the feed fines and solids in the upper zone, the opposite occurred for both the middle and lower zones where the relative percentages decreased in some proportion to increase in the feed fines. This could be interpreted as indicating poor capture of the fine particles by the reagents. As already noted for the overflow solids content, however, there is some doubt concerning the reality of the influence of the feed fines content and confirmation through additional testing is needed.

PERCOL 1697 + 1011

The Allied Colloids reagent Percol 1697 is a medium molecular weight high charge liquid cationic; Percol 1011 is a high molecular weight medium charge anionic powder PAM. Both were added as dilute solutions in the dosage ranges of 15.0 to 57.9 g/t cationic and 17.5 to 67.5 g/t anionic. No operating problems were observed during the tests. The feed contained 2.52 to 2.83% solids (0.38 - 0.43 stph) with 23.2 to 28.0% ash and 40.0 to 54.2% minus 44 μm fines.

Table 5 - Mobile plant results for Allied Colloids Percol 1697 + 1011 (flocculant combination D)

	Test		
	L	M	H
Date	23/07/83	24/07/83	24/07/83
Time	1635	1335	1555
Temperature (°C)	22.5	23	20.5
Cationic (g/t)	15.0	30.0	57.9
Anionic (g/t)	17.5	35.0	67.5
Reagent cost ($/t)*	0.082	0.164	0.314
Feed			
Solids content (%)	2.52	2.73	2.83
loading (lb/ft²/h)	15.28	16.57	17.18
rate (tph)	0.38	0.42	0.43
Ash content (%)	23.24	27.96	26.30
Minus 44 μm (%)	54.22	40.00	44.24
Overflow			
Wedge clarity (initial)	8	9	10
(average)	20	35	36
(final)	28	46	46
Solids content (ppm)	765	142	112
Water recovery (%)	72.4	72.4	72.4
Underflow			
Solids content (%)	15.36	16.12	16.37
Ash Content (%)	21.24	22.76	23.32
Solids recovery (%)	97.8	99.6	99.7
Solids distribution (%)			
Upper zone (<61 cm)	2.15	0.36	0.28
Middle zone (61-112 cm)	4.22	2.95	1.05
Lower zone (>112 cm)	93.63	96.69	98.67

*Dry tailings basis

Overflow

With increasing reagent dosage, the overflow solids contents decreased from 765 to 112 ppm with corresponding solids recoveries in the underflows increasing from 97.8 to 99.7%. The solids contents show excellent agreement with the wedge clarities of 28 to 46, all of which represent substantial improvement over the initial values of 8-10 (Table 5). Although clarity was primarily a function of dosage, reduced effectiveness of the reagent is indicated for an increase in the solids feed rate.

Equilibrium between the incoming feeds and the factors determining wedge clarity was achieved quickly in Tests M and H. Clarity increased rapidly beginning 10 minutes after the start of reagent addition, rising to the maximum readings of 46 some 10 to 15 minutes later. It appears that the equilibrium clarity may not have been attained within the 60 minutes in Test

L and that some improvement over the wedge value of 28 could have occurred with time, given the same feed and test conditions (Fig. 9a).

Underflow

With increasing dosage, average solids concentrations increased from 15.4 to 16.4%. However, it was determined that this increase occurred primarily as a result of the concurrent increase in feed solids content from 2.52 to 2.83% (Table 5). The corresponding average water contents of the underflows decreased in the range of 1102 to 1022 gallons of water per ton of dry solids with water recoveries in the overflow remaining constant at 72.4% in all three tests.

Solids Concentration Profile

The profiles show no evidence of an upper controlling concentration zone nor of a critical concentration indicating that at solids loadings of 15.3 to 17.2 $lb/ft^2/h$, the thickener was operating below full capacity. Between 0.3 and 2.2% of the solids in the thickener were located in the upper zone and between 1.1 and 4.2% in the middle zone (Table 5). Reagent dosage was the only identifiable factor controlling the relative quantities of solids in the two zones. Effective solids capture by this reagent combination was demonstrated by the fact that, despite a noticeable increase in solids throughput between Tests L and H, reduction in the relative percentages of solids in the two upper zones was achieved through the increase in dosage. While the increase in proportion of solids located in the lower zone is primarily attributable to the increase in solids loading, an indicated additional contribution from the increase in reagent dosage is consistent with the proportional decreases observed in the two overlying zones.

PRAESTOL 185K + 2935/73

The Stockhausen reagent Praestol 185K is a low molecular weight high charge liquid cationic; Praestol 2935/73 is a high molecular weight high anionic charge powder PAM. They were added as dilute solutions in the dosage ranges of 15.0 to 66.4 g/t and 17.5 to 77.5 g/t respectively. Low

feed tank level and problems in the supply lines were experienced at the 25-minute mark during Test M. The feeds contained 1.50 to 2.36% solids (0.23 - 0.36 stph) with 23.3 to 37.2% ash and 45.8 to 48.6% minus 44μm fines.

Table 6 - Mobile plant results for Praestol 185K + 2935/73 (flocculant combination E)

	Test		
	L	M	H
Date	24/07/83	25/07/83	25/07/83
Time	1815	1325	1545
Temperature (°C)	22	22	22
Cationic (g/t)	15.0	30.0	66.4
Anionic (g/t)	17.5	35.0	77.5
Reagent cost ($/t)*	0.108	0.215	0.476
Feed			
Solids content (%)	2.36	1.66	1.50
loading (lb/ft²/h)	14.32	10.04	9.06
rate (tph)	0.36	0.25	0.23
Ash content (%)	37.24	30.02	23.26
Minus 44 μm (%)	45.83	48.56	46.46
Overflow			
Wedge clarity (initial)	8	10	10
(average)	29	20	34
(final)	46	26	46
Solids content (ppm)	132	108	180
Water recovery (%)	72.6	72.1	71.6
Underflow			
Solids content (%)	15.03	11.94	9.11
Ash content (%)	22.52	24.22	21.78
Solids recovery (%)	99.6	99.5	99.2
Solids distribution (%)			
Upper zone (<61 cm)	0.39	0.48	0.84
Middle zone (61-112 cm)	1.40	0.80	1.81
Lower zone (>112 cm)	98.21	98.72	97.35

*Dry tailings basis

Overflow

With increasing reagent dosage, the overflow solids contents increased from 132 to 180 ppm, passing through a minimum of 108 ppm at the intermediate dosage level. This was accompanied by a small decrease in solids recovery in the underflow of 0.4% from 99.6 to 99.2%. Although the wedge clarities of 26 to 46 indicate significant improvement over the initial values of 8-10, the lowest reading of 26 obtained in Test M is not consistent with the fact that the lowest solids content of 108 ppm was also achieved in this test (Table 6). There was no obvious explanation for the apparent contradictions between the wedge clarities and solids contents on

the one hand and for the increase in solids content with increasing dosage on the other.

Clarification began 15 minutes from the start of reagent addition for Tests L and M and after 5 minutes for Test H. Subsequent interruptions in the clarification process are clearly evident for the low and medium dosages but much less so for the high (Fig. 10a). Clarification resumed after approximately 15 minutes in Test L and 5 minutes in Test H, wedge clarities in both tests rising to the maximum of 46 after 45 and 30 minutes respectively. This was not the case for Test M where wedge clarity reached a limiting value of 28 approximately 20-25 minutes into the test. Neither the usual test variables nor the supply-line problems during Test M offered adequate explanation for the interruptions. Assuming no inherent factors exist to limit the activity of this reagent combination at a specific dosage level for this particular tailings system, it can be speculated that the cause could have been related to undetected problems with reagent feeding.

Underflow

With increasing reagent dosage, the average underflow solids concentrations decreased from 15.0 to 9.1% by weight. The corresponding average water contents of the underflows increased in the range of 1130 to 1994 gallons of water per ton of dry solids with recovery of water in the overflow decreasing by 1% from 72.6 to 71.6%.

Solids Concentration Profile

The profiles show no evidence of an upper controlling concentration zone nor of a critical concentration indicating that at solids loadings of 9.1 to 14.3 $lb/ft^2/h$, the thickener was operating below full capacity. Between 0.4 and 0.8% of the solids in the thickener were located in the upper zone and between 0.8 and 1.8% in the middle zone (Table 6). Unexpectedly, the increase in relative quantities of solids in the upper zone between Tests L and H was almost completely accounted for by the increase in reagent dosage. However, a strong possibility that this increase was also connected in some way with the concurrent decrease in feed ash content was also indicated. Increase in the percentage of solids in the middle zone was most strongly related to and accompanied a decrease in the feed fines content. The effect of dosage was as indicated for the upper

zone. Correctness of the above relationships would be supported by the fact that those for the lower zone are of the exact opposite sign.

The curious behaviour of these reagents could be considered consistent either with a decrease in the apparent density of flocs with increasing dosage/decreasing feed ash or with the presence of mechanisms involving selective flocculation where reaction of the reagent(s) is based on preferential attachment to particles of some particular mineral species to the exclusion of others. Either or both of the above could have occurred if differences in the nature or make-up of the feeds can be inferred from the noticeable differences in ash content between the three tests.

DISCUSSION

In keeping with the principal objectives of the testwork, a number of mechanical, operational and related problems were identified or alluded to under various headings. These included the high underflow pumping rate, poor correspondence between wedge clarity and overflow solids content, inconsistency of the feed and its variations between tests, the limited number of observations, etc. While mechanical and procedural deficiencies can usually be easily resolved, such questions as the lack of agreement between wedge clarity and solids content require additional investigation. Inconsistency of the feed is the natural condition of thickener operation. Obtaining practical answers applicable to control of the water treatment process lies in investigating the feed and its variations not as incidental to the operation but as a potentially important causal agent. There must be at least implicit accommodation for feed inconsistency in the test design and related procedures. This would help ensure that the data are correct and relevant to such objectives as evaluation and optimization of reagents or identification of controlling parameters.

The available information provides neither the assurance that there was equivalence between the mobile plant and washery thickeners, as would be needed for scale-up, nor the certainty that the reagents were tested at their optimum or maximum capabilities. For the purpose of equivalence, more flexibility with some scope for varying the test thickener feed rate and underflow withdrawal method and rate would be necessary. Appropriate

mechanical adjustment by reference to the washery thickener operation requires basic technical information such as would be contained in the appended test specifications sheet (Appendix E). Such information would also be needed to simplify design of the field experiments and to reduce the amount of laboratory testing prior to the field work. To provide for reagent evaluation and optimization, more observations covering a broader range of feed conditions are needed. In this respect, reassessment of the test approach, especially as it applies to dual reagent addition, is warranted. As the basis for optimization, the development of control strategies is an integral part of the field work and one of its most important functions. With needed increasing attention to this aspect of the work, the installation with provision for testing of appropriate monitoring and control devices would be an urgent item.

UNDERFLOW

The question of underflow withdrawal rate was far from trivial. While its impact was more pronounced on the underflow, indirect effects on the overflow clarity would also be expected. For all tests with reagent, the underflow solids flux exceeded the feed flux and, therefore, steady-state was not fully established within the allowed test period. As determined from the differences in rates of increase and decrease respectively in solids content during the off-on periods of pump operation in Tests A-L to H and B-L_1, it is clear that continuous pumping at 15 igpm did not allow adequate time for settling and compaction of the solids. For continuous withdrawal, projections based on the solids fluxes and observed trends indicated that with extended testing, the underflow solids contents would probably have been lower and the overflow clarities higher than the reported final values (Tables 2-6). Similar projections showed that attaining equilibrium in the 1-hour test period, would have required pumping at a rate averaging about 12 igpm. Likewise, flowrates averaging between 2 and 4 igpm during the tests could have provided underflow solids contents in the neighbourhood of 30% by weight. An example taken from Test A-L shows that such low average flowrates, obtainable with increased frequency of pump operation for shorter periods would also have enabled relatively closer control on product quality (Fig. 11).

Within the 1-hour test period, the poorest underflow (3.9% solids) occurred for operation without flocculant. A decrease in the solids content generally accompanied an increase in reagent dosage, reagent D being a notable exception. However, in all cases but those involving reagents C and E, either the feed solids or the fines content emerged as overriding influences. For reagents A and D, increases in the underflow solids content were primarily attributable to increases in the feed solids content whereas similar change in the underflow for reagent B generally accompanied a decrease in the percentage of minus 44 μm fines in the feed (Fig. 14). These results would be consistent with the concepts of expression of water by compression from the weight of overlying solids and of high water retention by fine particles.

With continuous pumping, the highest average solids concentrations were achieved with reagent C (16.4%) followed by reagents D (16.0%), E (12.0%) and B (9.7%) over their respective dosage ranges. These results compare poorly with the values of 29 to 38% obtained in the washery and with the maxima of 30-40% obtained with intermittent pumping in the mobile plant. In fact, the effect of pumping procedure was far greater than any effects that could be attributed to either reagent or dosage. Meaningful evaluation of thickening performance of the individual reagents is, therefore, not possible. The existence of reasonably good correspondence between the test and washery underflow solids contents could be taken as confirming the generally lesser effects of variation in reagent and dosage on product quality as compared to those arising from variation in feed characteristics over the range of conditions for all tests (Fig. 12).

OVERFLOW

Use of even the poorest reagent at the lowest dosage provided substantially greater rejection of solids from the water along with varying degrees of improvement in wedge clarity and solids content over the results obtained with no flocculant. While the final wedge readings of between 12 and 46 most often constituted significant improvement over the initial readings of 7 to 12, they generally showed poor correspondence with the total overflow solids contents. The lack of agreement should come as no real surprise. It takes into account the fact that, in dilute suspensions, turbidity as measured by the wedge would arise substantially from the

presence of colloidal solids and/or colour from dissolved substances with little contribution from the coarser particles that may be present. If the purpose is control of total suspended solids in a washery effluent, then the question of the adequacy of turbidity measurement as being applicable to all cases needs to be investigated.

With increasing dosage, the reagents produced an average increase in wedge clarity of the overflow from an initial value of 10 to a final value of 27, accompanied by an average decrease in solids content from 2.15% solids to 324 ppm. The drop in solids content reflected a sizeable increase in solids recovery in underflow from 73% obtained without reagent to 99%. Water recovery in the overflow was primarily a function of the underflow pumping method, averaging 87% with intermittent withdrawal and 72% with continuous. On the overall, an increase in dosage from 17.5 to 70 g/t, in terms of the anionic, produced an increase of 13 units in the final wedge clarity from 22 to 35 with a corresponding decrease in average solids content of from 476 to 180 ppm. The overall average overflow solids content of 324 ppm obtained in the mobile plant during Tests B to E was more than 2.5 times the mean of 150 ppm obtained in the washery during the same period (Table A-1, Fig. 12). Unlike the case of the underflow, there was poor correlation between the overflow products of the two thickeners. This lack of correspondence confirms that the clarification process tends to be far more sensitive to the effects of differences in reagent than to the effects of variation in feed properties.

Although dosage was generally the principal factor controlling wedge clarity (the only one for reagent B), the results obtained with reagents A, C and D were also dependent on the solids loading and those for reagent E also on the feed fines content (Fig. 13). Reagents A and D showed similar behaviour in that an interaction between the dosage and feed solids content was found in both cases. The results of a change in feed solids content or dosage would, therefore, vary according to the level of the dosage or the loading respectively in the system. The effects of the interaction are much less apparent for the anionic reagent A used by itself and for this reason, these effects will be illustrated by reference to the reagent combination D. Maintaining a wedge clarity of 30 with this combination would require an increase in dosage amounting to the equivalent of $0.041 for each percentage increase in feed solids content in the range of 10-15 lb/ft^2/h (1.7-2.5%

solids). This compares to an increase in dosage amounting to the equivalent of $0.064 for each percentage increase in solids content in the range of 15-20 lb/ft²/h (2.5-3.3% solids). In similar fashion, an interaction between feed fines content and dosage for reagent combination E, would result in estimated added costs amounting to $0.068 for each percentage increase in minus 44 μm fines in the range of 45 to 47.5% but amounting to $0.106 for each percentage increase in the range of 47.5 to 50%. No indication of interaction was found for reagent combination C, and in this case, each percentage increase in solids content would require an increase in dosage equivalent to an added cost of $0.264 across the board.

Evaluating relative effectiveness of the reagents for clarification was complicated by the limited number of observations and the variability in feed properties and solids loadings between tests. To enable the required comparisons, the factor(s) that were common to the performance of all reagents were determined using multiple regression analysis of the combined data (n=34). With dosage expressed in terms of the anionic only, the relationship (r = 0.8151),

$$\text{Wedge clarity} = 11.37 + 1.72(\text{Dosage}) - 0.0290(\text{Dosage} \times \text{Fines})$$

shows that, the effect of dosage on overflow wedge clarity was a function of the percentage of minus 44 μm fines in the feed and that as the fines content increased, increasingly greater reagent additions would be needed to maintain clarity (Fig. 14). Comparison of the differences between the observed wedge clarities and values calculated from this equation indicates that, relative to the fines contents of their respective feeds, performance of reagents A, D and E would be considered better than average while that of reagents C and B would rank below the average over the same dosage ranges (Table 7). The means of the differences in the last column of the Table 7 show that the relative abilities of the reagents to cope with fine solids was in the approximate order E = D > A > C > B for the conditions tested.

Using the same relationship, calculation of corresponding costs for a range of wedge clarities for each reagent showed that Percol combination (D) would be the only one capable of achieving the target minimum wedge clarity of 30 with an expenditure below the maximum of $0.15 per tonne (Fig. 15). The cost of $0.13 per tonne for Percol was significantly lower than

Table 7 - Comparison of observed and calculated wedge clarities

Reagent	Test L			Test M			Test H			Mean
	Obs.	Calc.	Diff.	Obs.	Calc.	Diff.	Obs.	Calc.	Diff.	Diff.
A	13	8	+5	18	11	+7	15	16	-1	+3.7
B	13	18	-5	12	20	-8	13	34	-21	-7.6
B*	13	16	-3				46	47	-1	
C	17	19	-2	18	28	-10	46	45	+1	-3.7
D	28	14	+14	46	31	+15	46	41	+5	+11.3
E	46	18	+28	26	22	+4	46	40	+6	+12.7

*Test B-L: dosage=11.1 g/t; Test B-H: dosage=420 g/t.

the costs of $0.21 and $0.23 per tonne indicated for the Praestol and Superfloc reagent combinations (E and C) respectively. While it would be unable to meet the required performance level, the Crosfloc anionic (A) was, even used by itself, better than the Alchem combination (B). It should be remembered, however, that these comparisons are essentially valid only for the special case of addition at the rate of 0.86 parts cationic to 1 part anionic. There would be no sound rationale for assuming either that this would be the optimum ratio for all of the reagent combinations B to E or, for that matter, that any such ratio would necessarily remain constant under all conditions for a given set of reagents. For dual reagent use, rigorous comparison between reagent sets evidently requires optimization procedures to determine the least-cost cationic/anionic dosage combinations capable of giving maximum performance.

Optimization can be facilitated through an understanding of the effects of process variables and through the imposition of operational constraints. This can be illustrated by an example dealing with the possible effects of degree of charge (percent hydrolysis) of the anionic reagents. In addition to the similarities in behaviour noted earlier (Fig. 13) for the moderately-charged reagents A and D (≈19% hydrolyzed), the resemblances between performance of the more highly-charged reagents B relative to A and C and E relative to D indicate that the differences in behaviour could be attributable to differences in degree of charge of the anionic polyacrylamides. The data for the high-charge anionics were not suitable to allow distinguishing the effects of the cationics and the anionics used in combination. In the case of the high-charge anionics, wedge clarity was found to be dependent on dosage, subject to an interaction between the dosage and the minus 44 μm fines content in the feed as determined previously for all reagents combined (Fig. 14). For the

moderately-charged anionics A and D, the data indicated that wedge clarity was a function of the respective dosages of cationic and anionic, subject to an interaction between the two and to an interaction between the anionic and solids throughput. To maintain a given overflow clarity in this case, an increase in the feed solids content would primarily dictate an increase in the cationic dosage, the amount needed varying with the level of anionic (Fig. 16). Even if considered by itself, a cost constraint would be of substantial assistance for delimiting permissible dosage ranges for dual reagent evaluation. This would facilitate the planning and performance of field tests and would enhance the relevance of field and laboratory results.

In this regard, possible difficulties in scale-up between the laboratory and mobile plant need to be taken into account during preliminary bench testing for reagent screening. This was indicated by the great difference in the results obtained in the mobile plant and those obtained in subsequent bench tests for the Alchem reagents. While performance of these reagents in the mobile plant was generally poor by comparison with all the others, they performed very well in the bench flocculation tests and were ranked first in overall effectiveness followed by reagents D, C, and E in that order (Appendix F). There was no obvious explanation for the discrepancy which could have resulted from a number of factors including differences in the feeds, in the quality of reagent batches and/or in the structure or strength of flocs.

CONCLUSIONS

While the mobile plant tests were such that no definitive answers on reagent selection could be obtained for the Line Creek washery, much progress was made towards achieving the principal objectives dealing with mechanical, operational and experimental aspects of the plant. The conclusions reached are, therefore, more in the nature of recommendations which are intended to enhance the R & D potential of the plant and to ensure its capability for technology transfer.

The ultimate aims of the field work are to provide the industry with the answers that will lead to cost savings through technical and economic optimization of the water treatment operation. This can be achieved through

reagent selection, parameter selection and through the development of appropriate control strategies. For these purposes, the mobile plant must be capable of meeting the fundamentally important requirement of equivalence to enable scale-up to any given washery operation. This necessitates the provision for greater flexibility in pump operation for both the feed and the underflow of the thickener. By this is meant that both pumps must be able to provide ranges of flowrates and additionally, that the underflow pump should be capable of either continuous or intermittent operation. As provided for in the Test Specification Sheet (Appendix E), the condition of equivalence presupposes the availability of pertinent information to be provided by the washery operator.

For purposes of ensuring equivalence but even more important as it would apply to optimization, there should be no delay in acquiring and installing the appropriate instrumentation to enable concurrent work on the development of control strategies. In this regard, experimental design and associated procedures become preeminently important. The design needs to properly accommodate both the optimization techniques and the process of verification within a framework of limited time and labour. The testwork must also provide sufficient numbers of relevant data of unquestioned reliability that will also contribute to related modelling studies. The choice of design might be made between ANOVA and EVOP techniques or could include both. Whatever the case may be, replication with extended testing to cover a wide range of operating conditions appears essential.

Much valuable information was supplied by the samples obtained at 5 minute intervals during the tests and by the spigot samples taken at their conclusion. The need for the interval samples and the labour required for subsequent analysis would be greatly alleviated through the installation of monitors. Size analysis of the spigot samples in future would enhance the value of the information the samples can provide for a variety of purposes including control and model development. Care needs to be exercised in the preparation of samples for analysis. While the process of decantation may be justifiable on grounds of time savings, it carries the danger of loss of the finest size fractions. This would have serious consequences on the interpretation of results and could have been the factor responsible for the problems of reconciling the test underflow and feed ash contents. In this respect, the other possibility of residual moisture content must be taken

into account so that moisture analysis following drying of the samples should be performed at the same time as ash analysis. The determination of product solids contents should include analysis of total dissolved solids (TDS) in addition to total suspended solids (TSS). This would obviously be most important for the overflow samples where dissolved matter could contribute to turbidity. Size distribution of products would be considered one of the most important and revealing indicators of performance as related to settling or to solids capture by reagents. Neither the low suspended solids content in thickener overflow nor the fact that the underflow might contain flocculated or agglomerated solids should preclude size analysis of these products.

Among the subjects calling for investigation, the question of the relationship between turbidity as determined by the wedge and the suspended solids content needs immediate attention. The implications of an erroneous, total reliance on turbidity as a control parameter are obvious and could have a very significant impact on the consumption of reagents and the approach to control of the process in the washeries. A second topic of investigation deals with the possible relationship between reagent composition and its performance i.e., sensitivity to process variables and to particular feed properties. The extent to which it could be shown that performance is quantitatively related to the degree of hydrolysis of the reagents may give important insights into the factors governing the conformation of their molecules in solution and/or as controlling bonding mechanisms in a given solid-liquid system. Such information would be extremely useful with respect to selection or tailoring of reagents according to system characteristics.

The importance of close coordination of the laboratory and field investigations cannot be over-emphasized. It is imperative that the preliminary laboratory tests for reagent screening take into account the washery operational and economic requirements. These tests should also be designed in a way that will facilitate the field optimization process and that will provide data applicable over the long term to scale-up between the bench and the field. This would be enabled by detailed analysis aimed at thorough physical and chemical characterization of sample solids with provision for investigating interactions between the reagents as an integral part of the settling tests.

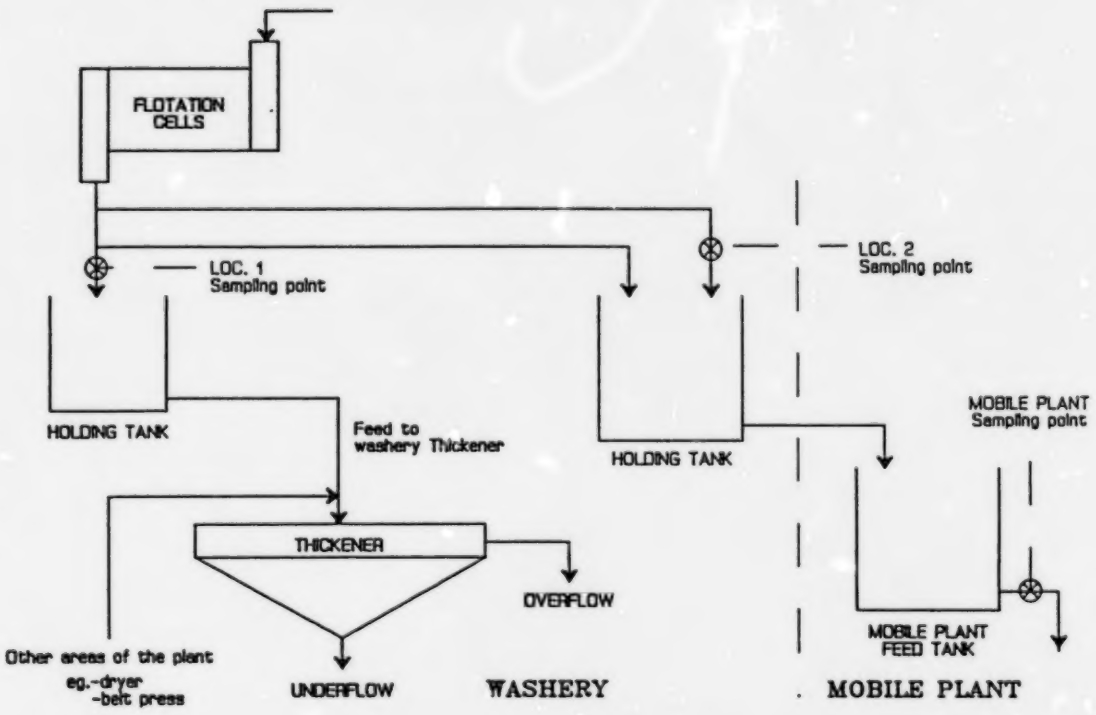

Fig. 1 - Interfacing of CNRL Line Creek washery with the mobile water treatment test plant

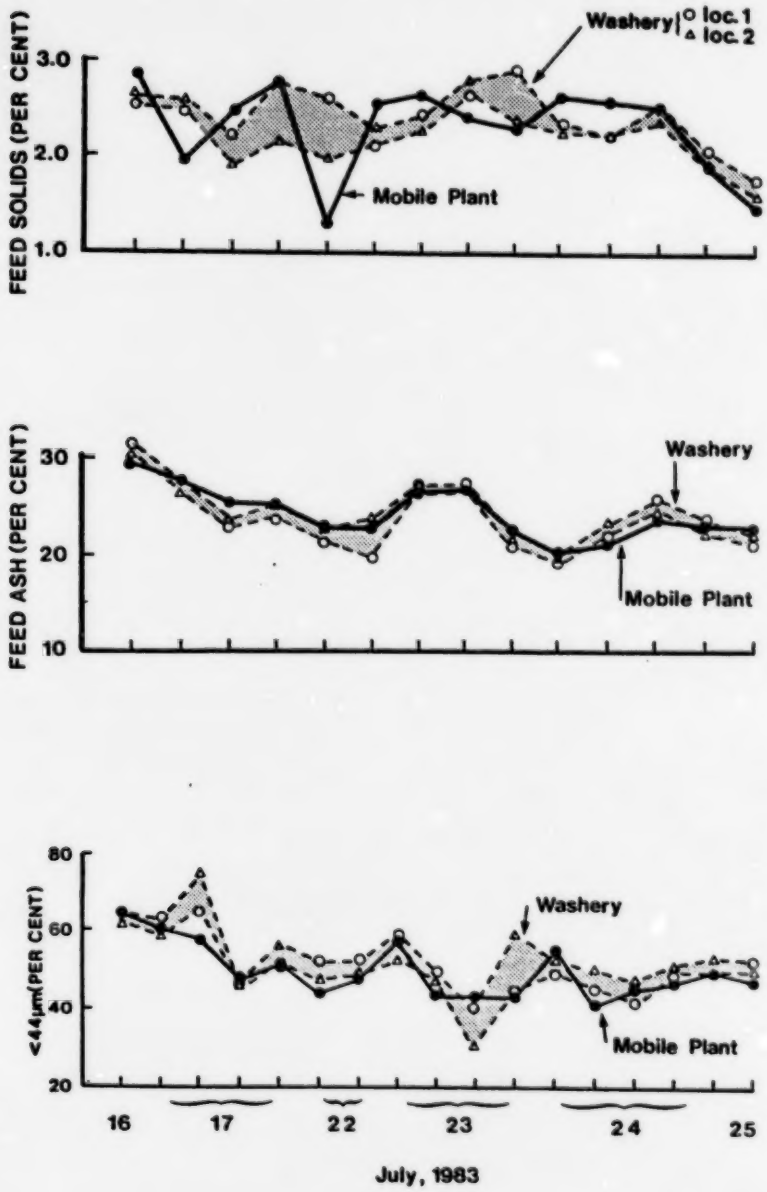

Fig. 2 - Solids, ash and fines contents of Line Creek washery and mobile plant thickener feeds, July, 1983

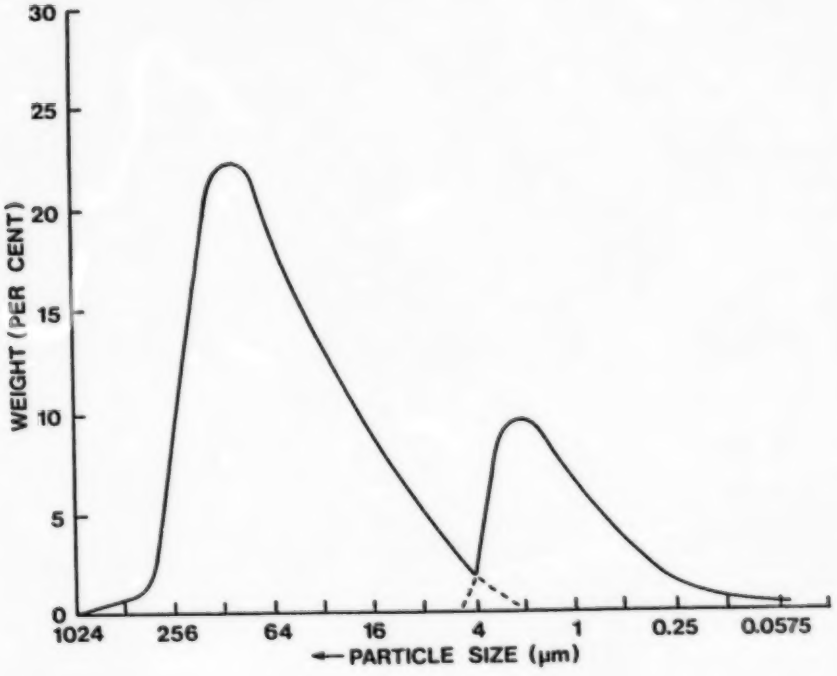

Fig. 3 - Average particle size distribution of Line Creek thickener feed (flotation tailings), July, 1983

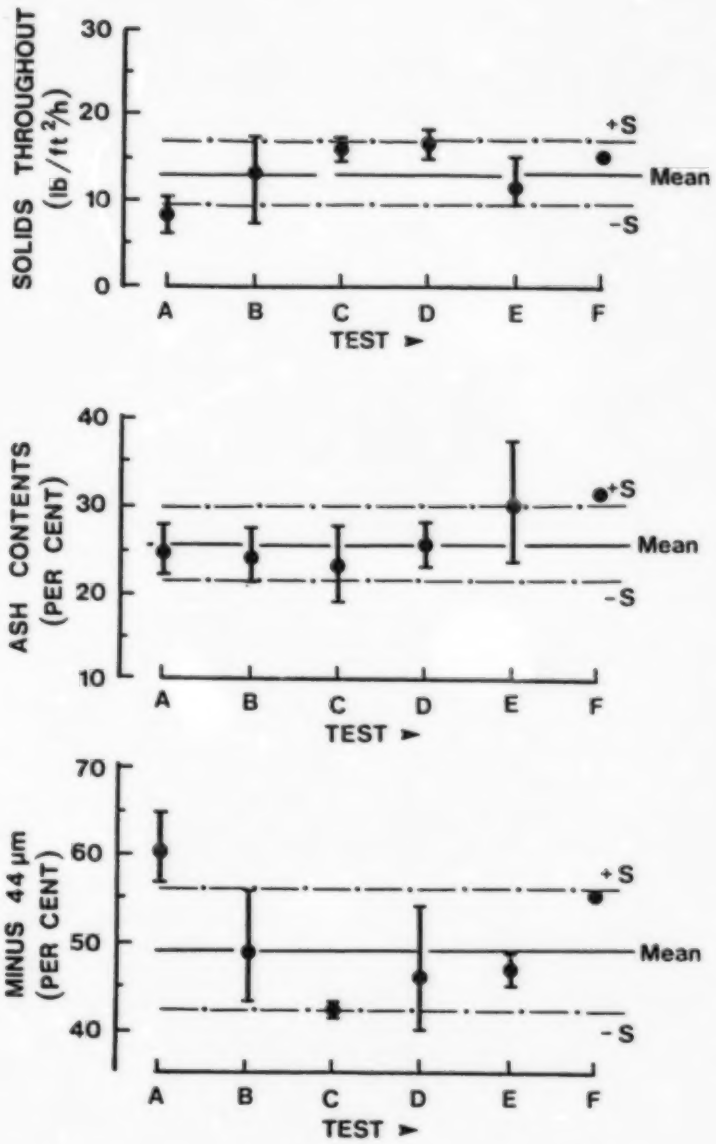

Fig. 4 - Variation of some characteristics of Line Creek and mobile plant thickener feeds, July, 1983

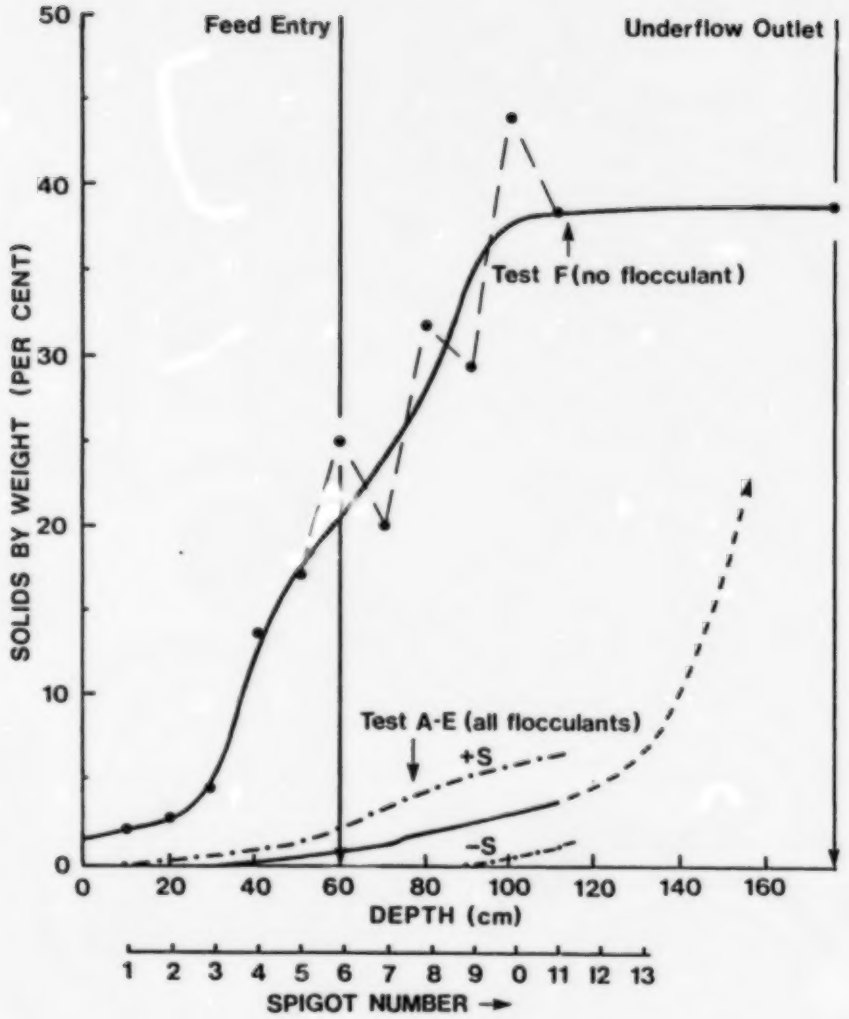

Fig. 5 - Final solids concentration profiles - mobile plant test thickener, July, 1983

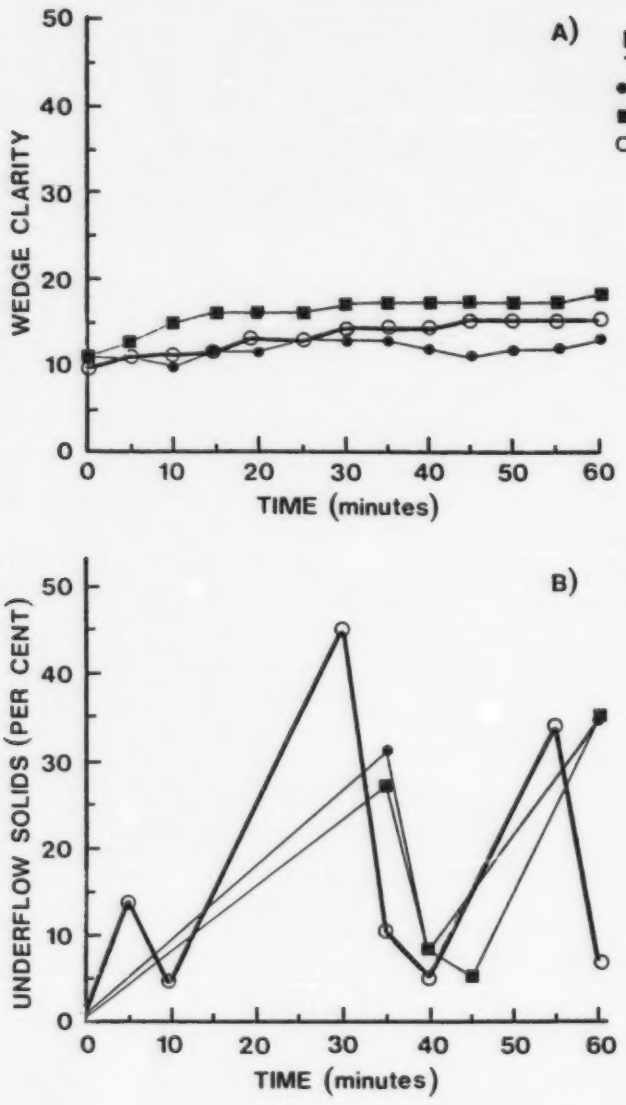

Fig. 6 - Changes in a) overflow wedge clarity and b) underflow solids content during tests with Crosfloc reagent CFA 50 - mobile plant thickener

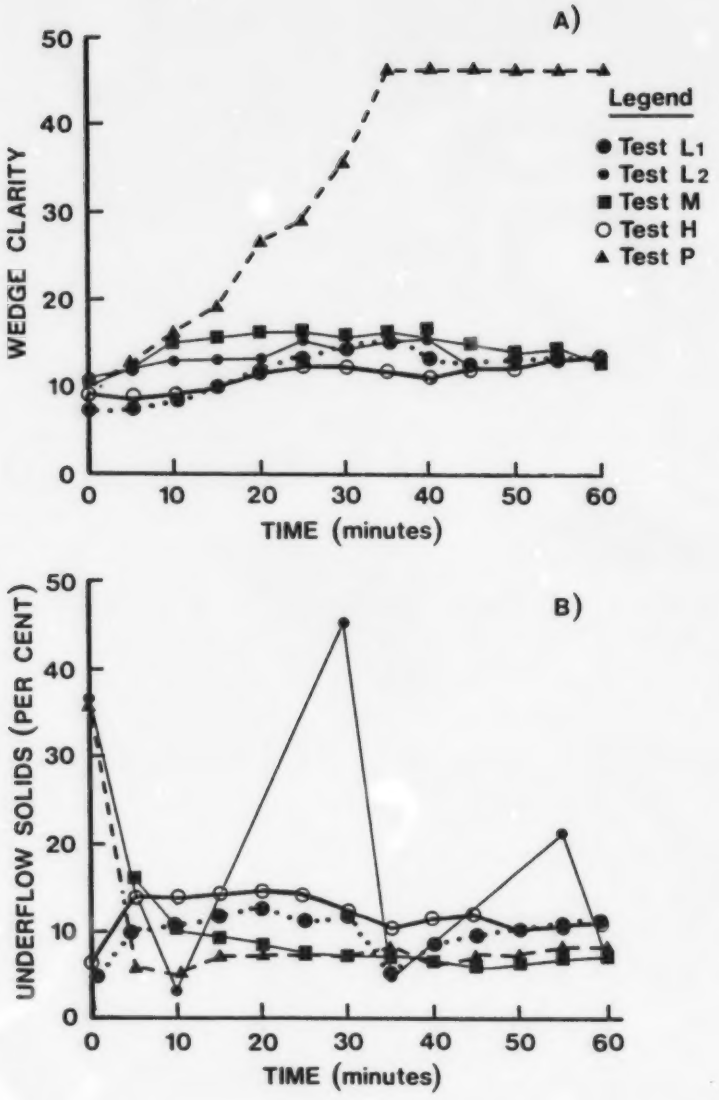

Fig. 7 - Changes in a) overflow wedge clarity and b) underflow solids content during tests with Alchem reagents 8852 and 8C26 - mobile plant thickener

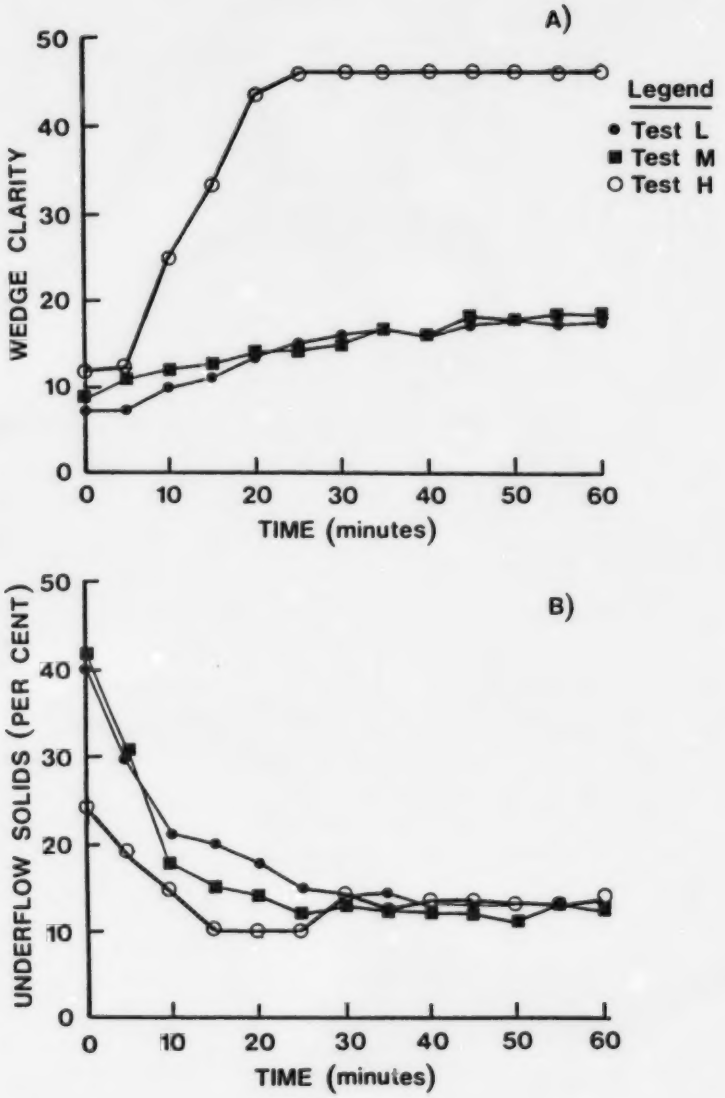

Fig. 8 - Changes in a) overflow wedge clarity and b) underflow solids content during tests with Superfloc reagents 355C and A130 - mobile plant thickener

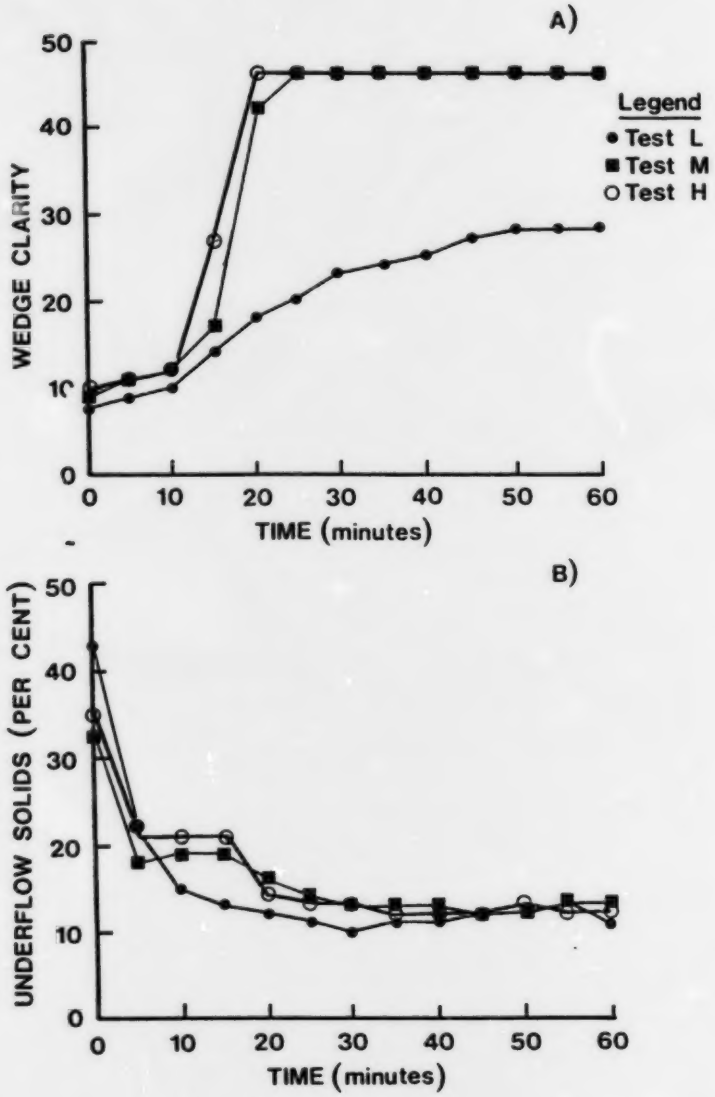

Fig. 9 - Changes in a) overflow wedge clarity and b) underflow solids content during tests with Percol reagents 1697 and 1011 - mobile plant thickener

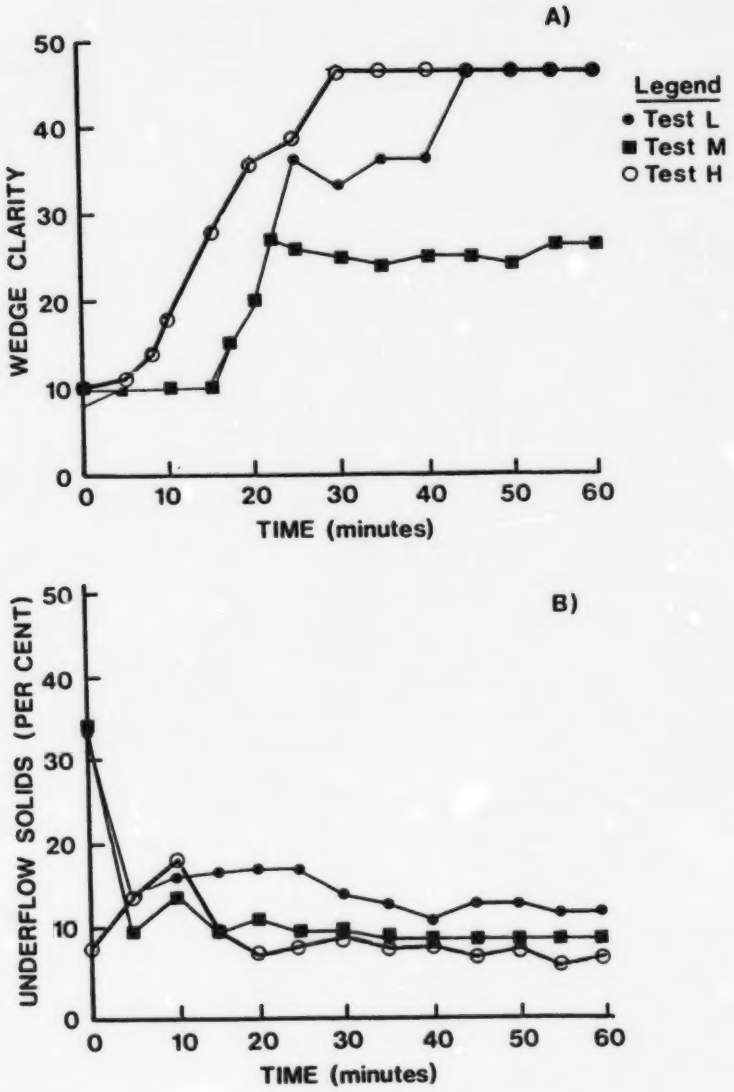

Fig. 10 - Changes in a) overflow wedge clarity and b) underflow solids content during tests with Praestol reagents 185K and 2935/73 - mobile plant thickener

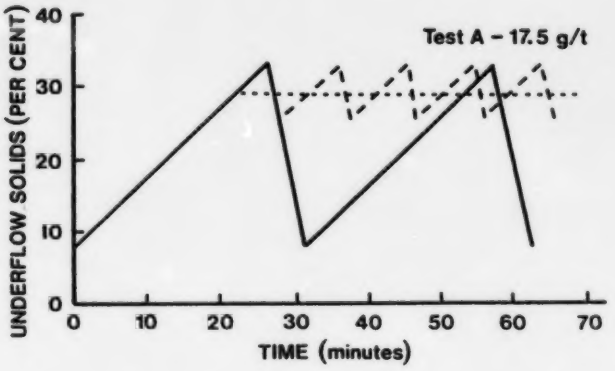

Fig. 11 - Effect of pumping frequency on underflow solids content using intermittent withdrawal at 15 igpm - mobile plant test thickener

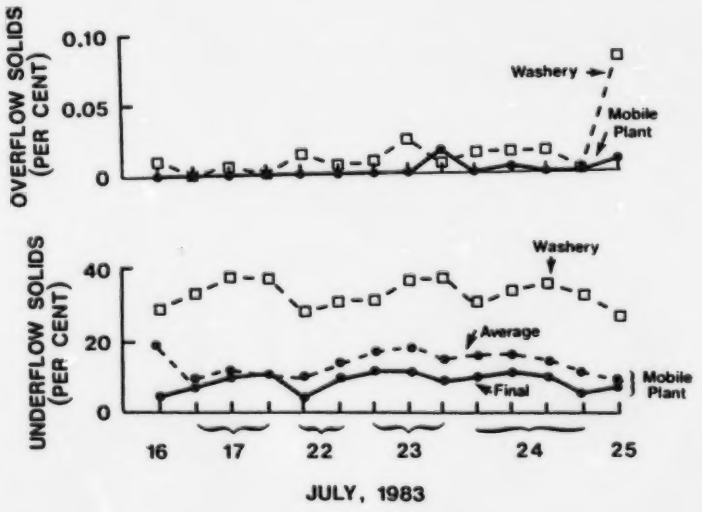

Fig. 12 - Washery and mobile plant overflow and underflow solids contents for tests with reagents B - E, July, 1983

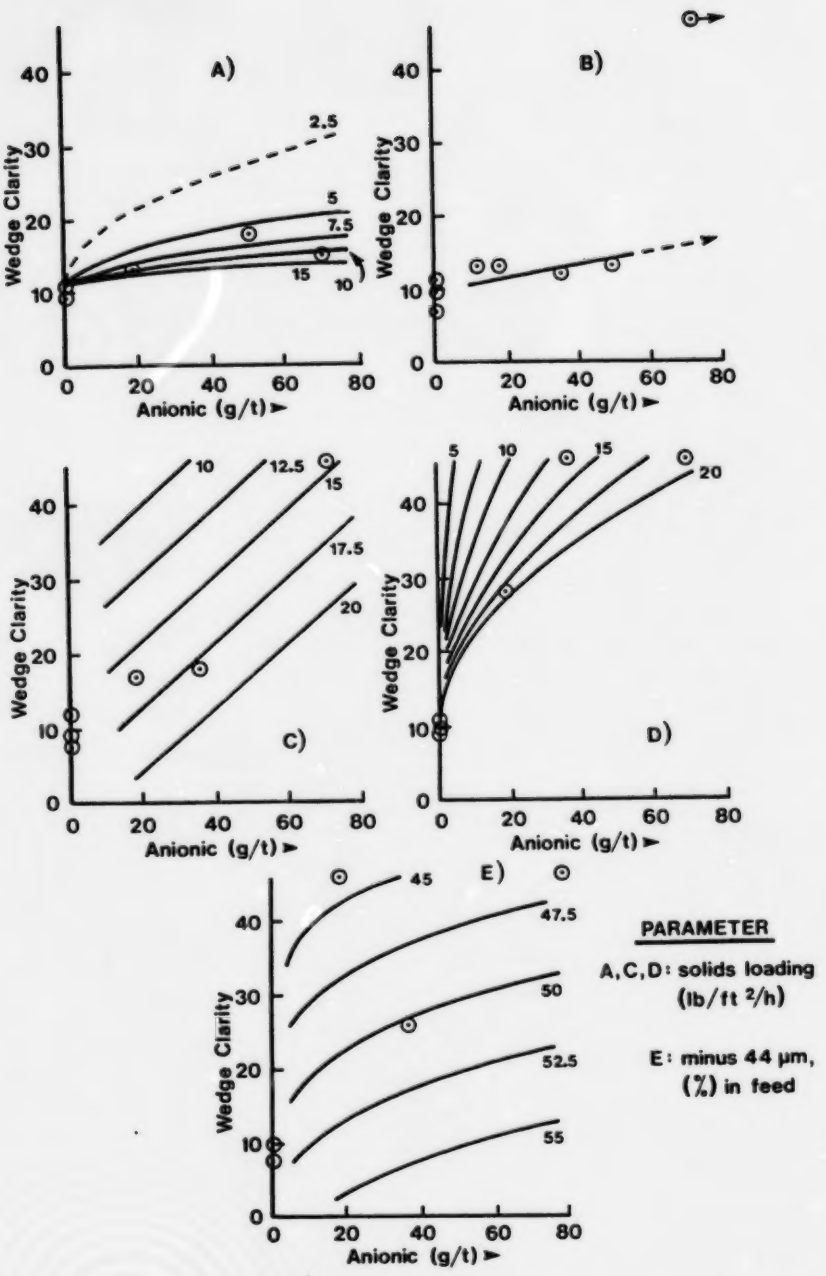

Fig. 13 - Effect of dosage and other factors on mobile plant test thickener overflow wedge clarity for reagents A - E

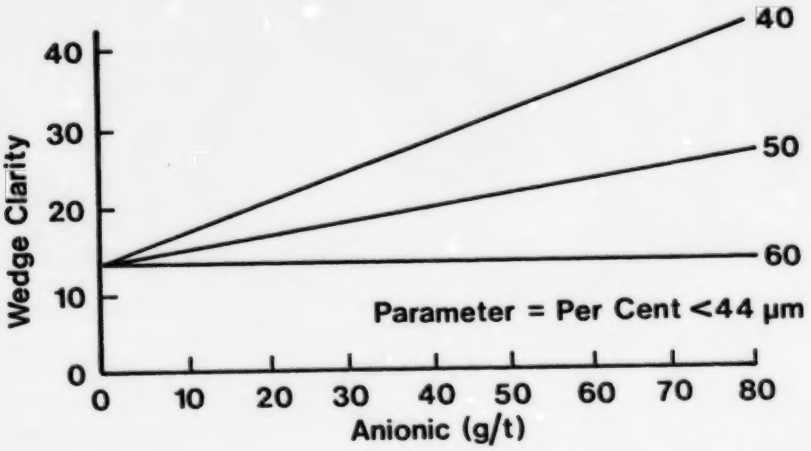

Fig. 14 - Effects of dosage and feed fines content on mobile plant test thickener overflow wedge clarity - all reagents

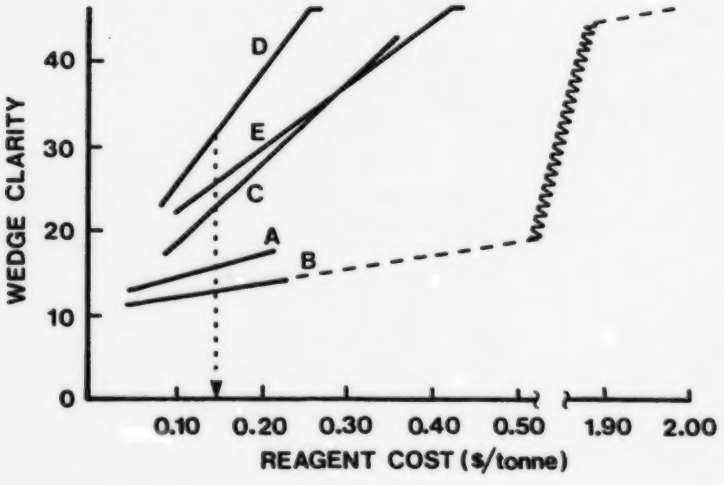

Fig. 15 - Comparison of clarification costs for reagents A - E

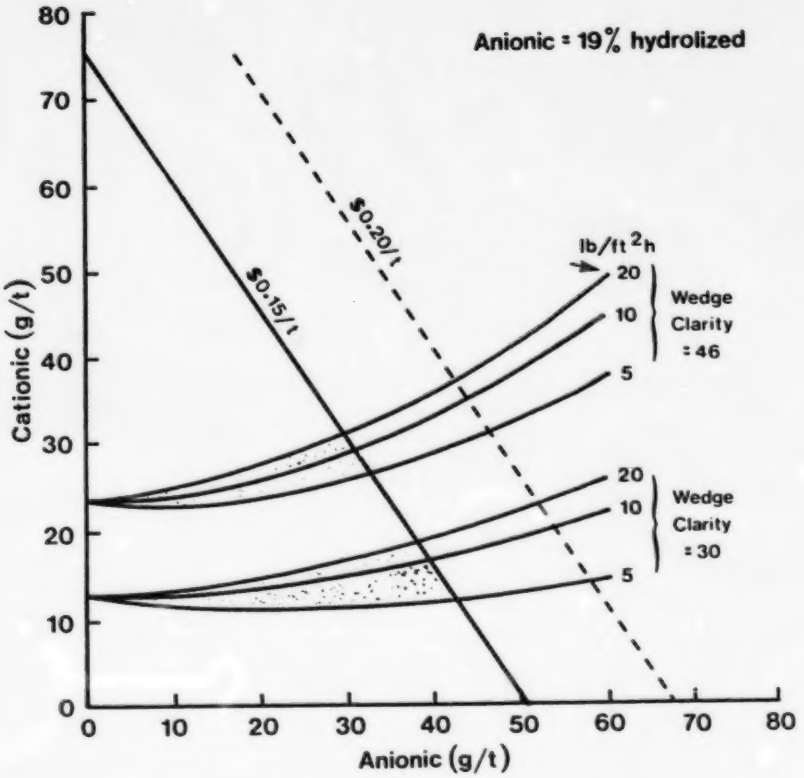

Fig. 16 - Effects of solids loading and cationic-anionic dosages on clarification with cost constraints

APPENDIX A - MONITORING RESULTS AT LINE CREEK WASHERY - JULY 16 to July 25, 1983

MONITORING RESULTS AT LINE CREEK WASHERY

Analytical data for solids, ash and fines contents are summarized in Tables A-1, A-2 and A-3 respectively. Based on a composite of the samples from locations 1 and 2 shown in Fig. 1, the washery feed solids content averaged 2.32% in the range of 1.70 to 2.72%, the ash content averaged 24.0% in the range of 19.5 to 30.9% and the fines content averaged 51.0% in the range of 34.5 to 70.5%. Between July 16 and July 25, 1983, all three feed parameters showed downward trends with the solids dropping by 0.4%, the ash by 4.6% and the fines by 11.0% on the average.

During the same period, the mean solids content of thickener overflow was 0.0147% solids (147 ppm) in the range of <0.001 to 0.040% and showed an upward trend. The underflow solids content averaged 33.3% overall, showed a daily fluctuation in the range of 28.7 to 37.5%, and was decreasing with time. There was no evidence of significant relationships between thickener products and feed characteristics.

Table A-1 - Monitoring results - Line Creek washery solids content (%)

Date (1983)	Time	Feed			U'Flow (Washery)	O'Flow (Washery)
		Washery Location		Mobile Plant		
		No. 1	No. 2			
July 16	1625	2.52	2.60	2.82	29.04	0.011
17	1145	2.48	2.58	1.94	33.60	<0.001
	1445	2.20	1.90	2.46	38.29	0.006
	1750	2.78	2.16	2.75	37.95	<0.001
22	1255	2.60	1.94	1.27	28.66	0.016
	1730	2.15	2.28	2.55	31.21	0.007
23	1100	2.44	2.24	2.62	31.72	0.009
	1410	2.65	2.80	2.40	37.26	0.025
	1635	2.92	2.36	2.27	37.72	0.007
24	1335	2.35	2.24	2.63	30.16	0.015
	1555	2.23	2.22	2.60	34.60	0.015
	1815	2.55	2.39	2.54	35.90	0.016
25	1325	2.06	1.91	1.92	32.98	<0.001
	1545	1.79	1.60	1.50	26.88	0.079
Mean		2.41	2.23	2.31	33.28	0.015
s.d.		0.30	0.32	0.47	3.80	0.020

Table A-2 - Results of Line Creek washery thickener monitoring for product ash contents

Date (1983)	Time	Feed			Underflow	
		Washery Location		Mobile Plant	Washery	Mobile plant
		No. 1	No. 2			
July 16	1625	31.31	30.42	29.28	24.15	23.25
17	1145	27.32	26.13	27.58	21.31	24.76
	1445	22.75	23.54	25.25	20.07	23.55
	1750	23.64	24.74	25.32	21.46	20.25
22	1255	21.47	22.35	22.78	19.39	20.25
	1730	19.77	23.55	22.77	21.78	19.77
23	1100	27.25	26.55	26.25	21.01	22.12
	1410	27.23	26.55	26.77	21.21	24.25
	1635	21.02	22.22	22.52	19.52	21.24
24	1145	22.71	23.61	22.75	18.62	22.25
	1335	19.36	19.65	20.16	19.25	22.76
	1555	22.18	23.25	21.26	19.76	23.32
	1815	25.77	24.76	23.63	24.23	22.52
25	1325	23.57	22.36	22.85	23.45	24.22
	1545	21.20	22.53	22.52	19.63	21.78
Mean		23.77	24.15	24.11	20.99	22.42
s.d.		3.35	2.54	2.52	1.79	1.54

Table A-3 - Results of Line Creek washery thickener monitoring for minus 44 μm (325 mesh) fines content

Date (1983)	Time	Feed		
		Washery location		Mobile plant
		No. 1	No. 2	
July 8	1420	64.16	62.07	64.91
	1600	62.69	58.19	59.74
9	1330	65.39	75.60	57.15
16	1625	45.74	45.78	47.14
17	1145	50.95	55.32	50.68
	1445	51.13	46.54	43.21
	1750	50.92	48.31	46.32
22	1255	58.30	51.95	56.43
	1730	48.26	47.14	42.59
23	1100	39.27	29.75	42.62
	1410	44.16	58.50	42.43
	1635	48.21	51.36	54.22
24	1145	42.68	50.45	55.27
	1335	44.36	49.00	40.00
	1555	42.00	46.32	44.24
	1815	48.55	50.48	45.83
25	1325	48.82	52.23	48.56
	1545	51.67	49.31	46.86
Mean		50.40	51.57	49.32
s.d.		7.66	9.08	7.06

APPENDIX B - SIZE ANALYSIS OF WASHERY AND MOBILE PLANT FEEDS

Table B-1 - Screen analysis of feed solids for tests with CFA 50

Size Fraction (μm)	Test L			Test M			Test H		
	Washery		Mobile	Washery		Mobile	Washery		Mobile
	1	2	plant	1	2	plant	1	2	plant
+ 595	-	-	-	1.49	-	-	1.92	-	-
595 - 250	-	1.72	1.75	1.49	1.82	2.60	3.85	-	2.04
250 - 149	3.77	3.45	3.51	2.99	7.27	6.49	7.69	4.88	8.16
149 - 105	7.55	6.90	7.02	7.46	9.09	10.39	7.69	7.32	10.20
105 - 74	9.43	10.34	7.02	5.97	7.27	7.79	7.69	7.32	10.20
74 - 44	15.09	15.52	15.79	17.91	16.36	12.99	5.77	4.88	12.25
- 44	64.16	62.07	64.91	62.69	58.19	59.74	65.39	75.60	57.15

Table B-2 - Screen analysis of feed solids for tests with Alchem

Size Fraction (μm)	Test L_1			Test L_2			Test M		
	Washery		Mobile	Washery		Mobile	Washery		Mobile
	1	2	plant	1	2	plant	1	2	plant
+ 595	-	-	-	0.93	-	-	-	-	-
595 - 250	2.13	2.41	2.30	1.85	2.25	2.11	2.83	3.19	1.37
250 - 149	11.70	12.05	12.64	11.11	13.48	12.63	16.98	14.89	9.59
149 - 105	13.83	14.46	13.79	11.11	12.36	12.63	11.32	12.77	12.33
105 - 74	12.77	12.05	12.64	12.04	12.36	13.68	9.43	10.64	12.33
74 - 44	13.83	13.25	11.49	12.04	11.24	12.63	8.49	3.19	13.70
- 44	45.74	45.78	47.14	50.92	48.31	46.32	50.95	55.32	50.68

Size fraction (μm)	Test H			Test P		
	Washery		Mobile	Washery		Mobile
	1	2	plant	1	2	plant
+ 595	-	0.99	-	0.43	-	0.32
595 - 250	2.27	2.97	2.47	1.84	2.12	3.22
250 - 149	13.64	11.88	12.35	14.61	16.94	16.56
149 - 105	12.50	13.86	14.81	11.91	13.03	12.86
105 - 74	10.23	9.90	13.58	10.78	9.45	9.65
74 - 44	10.23	13.86	13.58	2.13	6.51	0.96
- 44	51.13	46.54	43.21	58.30	51.95	56.43

Table B-3 - Screen analysis of feed solids for tests with Superfloc

Size fraction (μm)	Test L			Test M			Test H		
	Washery		Mobile	Washery		Mobile	Washery		Mobile
	1	2	plant	1	2	plant	1	2	plant
+ 595	-	-	1.01	0.09	0.12	0.11	-	1.15	-
595 - 250	1.80	-	3.03	2.47	3.00	2.28	1.58	2.30	2.40
250 - 149	13.51	12.26	13.13	16.95	20.42	17.25	12.87	11.49	17.62
149 - 105	13.51	14.15	14.14	16.35	20.07	15.18	14.87	12.64	14.42
105 - 74	14.41	12.26	14.14	11.84	13.49	10.63	9.55	12.64	10.95
74 - 44	12.61	2.83	12.12	13.03	13.15	11.93	12.87	12.64	12.02
- 44	44.16	58.50	42.43	39.27	29.75	42.62	48.26	47.14	42.59

Table B-4 - Screen analysis of feed solids for tests with Percol

Size fraction (μm)	Test L			Test M			Test H		
	Washery		Mobile	Washery		Mobile	Washery		Mobile
	1	2	plant	1	2	plant	1	2	plant
+ 595	-	-	-	-	-	-	-	-	-
595 - 250	1.79	0.90	1.20	1.74	1.00	2.11	3.00	1.05	1.92
250 - 149	11.61	9.91	12.05	13.04	13.00	14.74	14.00	9.47	13.46
149 - 105	13.39	11.71	13.25	14.78	14.00	15.79	14.00	14.74	15.38
105 - 74	12.50	12.61	12.05	13.04	12.00	13.68	15.00	13.68	12.50
74 - 44	12.50	13.51	7.23	13.04	11.00	13.68	12.00	14.74	12.50
- 44	48.21	51.36	54.22	44.36	49.00	40.00	42.00	46.32	44.24

Table B-5 - Screen analysis of feed solids for tests with Praestol

Size fraction (μm)	Test L			Test M			Test H		
	Washery		Mobile	Washery		Mobile	Washery		Mobile
	1	2	plant	1	2	plant	1	2	plant
+ 595	-	-	-	1.19	-	-	-	-	1.41
595 - 250	0.97	0.93	1.04	2.38	-	2.86	2.25	-	2.82
250 - 149	10.68	10.28	13.54	10.71	8.96	12.86	11.24	10.96	12.68
149 - 105	12.62	12.15	13.54	13.10	11.94	11.43	11.24	10.96	12.68
105 - 74	10.68	13.08	10.42	11.90	10.45	11.43	11.24	10.96	11.27
74 - 44	16.50	13.08	15.63	11.90	16.42	12.86	12.36	17.81	12.68
- 44	48.55	50.48	45.83	48.82	52.23	48.56	51.67	49.31	46.46

Table B-6 - Screen analysis of feed solids for test with no flocculant

Size fraction (μm)	Washery		Mobile plant
	1	2	
+ 595	0.63	-	0.13
595 - 250	4.18	3.69	2.56
250 - 149	8.02	7.44	10.51
149 - 105	7.25	8.86	7.18
105 - 74	13.67	10.28	11.47
74 - 44	23.57	19.28	12.88
- 44	42.68	50.45	55.27

APPENDIX C - WEDGE CLARITIES AND UNDERFLOW SOLIDS CONTENTS DURING MOBILE PLANT WATER TREATMENT TESTS

Table C-1 - Wedge clarity and underflow solids contents during tests with Crosfloc CFA 50

Time (min)	Test L		Test M		Test H	
	Wedge clarity	U'Flow solids	Wedge clarity	U'Flow solids	Wedge clarity	U'Flow solids
0	11	-	11	-	10	-
5	11	5	13	4.5	11	14
10	10	*	15	*	11	4
15	12	*	16	*	12	*
20	12	*	16	*	13	*
25	13	*	16	*	13	* → R
30	13	R	17	R	14	45
35	13	31	17	27	14	10
40	12	8	17	8	14	5
45	11	*	17	5	15	*
50	12	*	17	*	15	* → R
55	12	* → R	17	* → R	15	34
60	13	34	18	35	15	7

* Underflow pump off
R Underflow pump started

Table C-2 - Wedge clarity and underflow solids contents during tests with Alchem 8852 and 8C26

Time (min)	Test L_1		Test L_2		Test M	
	Wedge clarity	U'Flow solids	Wedge clarity	U'Flow solids	Wedge clarity	U'Flow solids
0	11	37	7	3-5	10	-
5	12	15	7	10	12	16
10	13	4	8	10.5	15	10
15	13	*	10	11.5	15.5	9.5
20	13	*	12	12.5	16	8.5
25	15	* → R	13	11	16	7.5
30	14	45	14	11.5	15.5	7
35	15	4	16	5	16	7
40	15	*	13	8	15.5†	6.5†
45	12	*	12	9	14.5	6
50	12	* → R	13	9.5	13.5	6.5
55	13	21	13	11	14	7
60	13	7	13	10.5	12 **	7

Time (min)	Test H		Test P	
	Wedge clarity	U'Flow solids	Wedge clarity	U'Flow solids
0	9	6	10.5	36
5	8.5	14	12.5	6
10	9	13.5	16	5
15	10	14	19	7
20	11.5†	14.5†	26.5	7
25	12	14	29	7
30	12	12	35.5	7
35	11.5	10	46	8
40	11	11	46	6
45	12	11.5	46	7
50	12	10	46	7
55	13	10	46	8
60	13	11	46	8

* Underflow pump off
R Underflow pump started
† Low feed tank level
** Washery clarity = 32

Table C-3 - Wedge clarity and underflow solids contents during tests with Cyanamid Superfloc 355C and A130

Time (min)	Test L		Test M		Test H	
	Wedge clarity	U'Flow solids	Wedge clarity	U'Flow solids	Wedge clarity	U'Flow solids
0	7.5	40	9	42	12	24
5	7.5	29	11	31	12.5	18.5
10	10	21	12	18	24.5	14.5
15	11	20	12.5	15	33	10
20	13.5	18	14	14	43.5	10
25	15	14.5	14	12	46	10
30	16†	14†	15	13	46	14
35	16.5	14	16.5	12.5	46	12.5
40	15.5	13	16	12	46	13
45	17	13	18	12	46	13.5
50	17.5	13	17.5	11	46	13
55	17	12.5	18	13	46	13
60	17	12	18 **	13	46 **	13

† Low level in Feed tank
** Washery clarity = 42

Table C-4 - Wedge clarity and underflow solids contents during tests with Allied Colloids Percol 1697 and 1011

Time (min)	Test L		Test M		Test H	
	Wedge clarity	U'flow solids	Wedge clarity	U'flow solids	Wedge clarity	U'flow solids
0	8	43	9	33	10	35.5
5	9	22	11	18	11	21
10	10	15	12	19	12	21
15	14	13	17	19	27	21
20	18	12	42	16	46	14
25	20	11	46	14	46	13
30	23	10	46	13	46	13
35	24	11	46	13	46	12
40	25	11	46	13	46	12
45	27	12	46	12	46	12
50	28	12	46	12	46	12
55	28 **	13	46	13	46	12
60	28	11	46	13	46	12

** Washery clarity = 46

Table C-5 - Wedge clarity and underflow solids contents during tests with Stockhausen Praestol 185K and 2935/73

Time (min)	Test L		Test M		Test H	
	Wedge clarity	U'flow solids	Wedge clarity	U'flow solids	Wedge clarity	U'flow solids
0	8	33	10	33.5	10	8
5	10	14	10	10	11	14
10	10	16	10	14	18	18
15	10	16.5	10	10	28	10
20	20	17	20	11.5	36	7
25	36	17	26†	10†	38	8
30	33	14	25	10††	46	9
35	36	13	24	9	46	8
40	36	11	25	9	46	8
45	46	13	25	9	46	7
50	46	13	24	9	46	8
55	46	12	26	9	46	6
60	46	12	26	9	46	7

† Low feed tank level

†† Problem in supply lines

APPENDIX D - SOLIDS CONCENTRATION PROFILES
MOBILE PLANT TEST THICKENER

Table D-1 - Final solids concentration profiles for tests with Crosfloc CFA 50

Spigot No.	Depth (cm)	Test L	Test M	Test H
-	O'flow	0.006	0	0
1	10.16	0	0.005	0
2	20.32	0	0	0
3	30.48	0	0.005	0
4	40.64	0.018	0.006	0
5	50.80	0.021	0.006	0
6	60.96	0.032	0.006	0.028
7	71.12	0.017	0.005	0.005
8	81.28	0.078	0.027	0.139
9	91.44	0.195	0.006	0.189
10	101.60	0.301	0.016	0.212
11	111.76	0.386	0.081	0.205
U'flow	176.00	27.96	32.75	39.71

Table D-2 - Final solids concentration profiles for tests with Alchem 8852 and 8C26

Spigot No.	Depth (cm)	Test L_1	Test L_2	Test M	Test H	Test P
-	O'flow	0	0	0	0	0
1	10.16	0	0.006	0.040	0	0.030
2	20.32	0	0	0.084	0	0.047
3	30.48	0.055	0.011	0.053	0	0
4	40.64	0.067	0.094	0.070	0.019	0.021
5	50.80	0.010	0.196	0.127	0.025	0.030
6	60.96	0.161	0.533	0.074	0.077	0.017
7	71.12	0.392	0.800	0.055	0.083	0
8	81.28	0.498	1.052	0.161	0.121	0.033
9	91.44	0.498	1.102	0.323	0.236	0.215
10	101.60	0.553	1.121	0.455	0.422	0.040
11	111.76	0.637	1.157	0.587	0.585	0.464
U'flow	176.00	5.09	10.86	7.70	10.64	5.09

Table D-3 - Final solids concentration profiles for tests with Cyanamid Superfloc 355C and A130

Spigot No.	Depth (cm)	Test L	Test M	Test H
-	O'flow	<0.001	<0.001	0.002
1	10.16	0.045	0.013	0.021
2	20.32	0.007	0.033	0.022
3	30.48	0.079	0.074	0.006
4	40.64	0.005	-	0.015
5	50.80	0.002	0.178	0.083
6	60.96	0.023	0.122	0.107
7	71.12	0.010	0.187	0.116
8	81.28	0.243	0.172	0.138
9	91.44	0.282	0.180	0.176
10	101.60	0.251	0.273	0.229
11	111.76	0.331	0.128	0.241
U'flow	176.00	11.51	11.70	9.91

Table D-4 - Final solids concentration profiles for tests with Allied Colloids Percol 1697 and 1011

Spigot No.	Depth (cm)	Test L	Test M	Test H
-	O'flow	0.016	<0.001	0.004
1	10.16	0.011	0.008	0.003
2	20.32	0.005	0.008	0.014
3	30.48	0.020	0.004	0.012
4	40.64	0.029	0.003	0.002
5	50.80	0.252	0.030	0.040
6	60.96	-	0.046	0.004
7	71.12	0.138	0.100	0.003
8	81.28	0.314	0.178	0.012
9	91.44	0.409	0.323	0.124
10	101.60	0.476	0.338	0.118
11	111.76	0.451	0.417	0.247
U'flow	176.00	9.93	10.14	11.57

Table D-5 - Final solids concentration profiles for tests with Stockhausen Praestol 185K and 2935/73

Spigot No.	Depth (cm)	Test L	Test M	Test H
-	O'flow	<0.001	<0.001	0.006
1	10.16	0.002	0.001	0.001
2	20.32	-	0.001	-
3	30.48	0.040	0.006	-
4	40.64	0.009	0.039	0.039
5	50.80	0.002	0.008	0.035
6	60.96	0.038	0.020	0.045
7	71.12	0.001	0.045	0.045
8	81.28	0.029	0.040	0.101
9	91.44	0.084	0.051	0.128
10	101.60	0.101	0.047	0.086
11	111.76	0.336	0.044	0.094
U'flow	176.00	10.69	5.70	6.94

Table D-6 - Final solids concentration profile for test with no flocculant

Spigot No.	Depth (cm)	Solids content	Ash content
-	O'flow	0.139	-
1	10.16	0.219	27.25
2	20.32	0.279	26.24
3	30.48	0.434	27.25
4	40.64	1.343	23.45
5	50.80	1.699	23.25
6	60.96	2.503	24.24
7	71.12	2.003	19.78
8	81.28	3.197	22.21
9	91.44	2.948	21.25
10	101.60	4.400	34.96
11	111.76	3.850	21.22
U'flow	176.00	3.900	22.25

APPENDIX E - SPECIFICATIONS SHEET

[Confidential]

WASHERY THICKENER/WATER TREATMENT TESTING
SPECIFICATIONS SHEET

Washery _____ Date: _____

By: _____

---

1. THICKENER

Type:_____ Manufacturer:_____

Diameter:_____

Depth:_____

Rake: Speed_____ rph; Maximum Torque _____

Design capacity:_____

Underflow Pump:

Type:_____ HP:_____

Flowrate:_____

continuous [ ];

intermittent [ ] - fixed cycle [ ] at _____

- variable cycle [ ] based on _____

_____ Control Method: _____

---

2. FEED CHARACTERISTICS

Flowrate:_____

Solids content:_____

Source(s):_____

_____ Flowsheet Attached [ ]

Significant changes in feed and/or plant & mine operations since commissioning the thickener:_____

_____

_____

_____

_____

3. REAGENTS

Current: Cationic _____, added _____ at a dosage of _____. Dilution: _____

Addition Point(s): _____

Anionic _____, added _____ at a dosage of _____. Dilution: _____

Addition Point(s): _____

Unit costs: Cationic _____ Anionic _____

Basis for Selection: _____

Date First Used: _____

Preparation Method(s)/Equipment: _____

_____

_____

Control Method/Procedure: _____

_____

_____

Performance:

Overflow - Satisfactory [ ]; Fair [ ]; Poor [ ]; Variable [ ]

Best when _____

Worst when _____

Underflow - Satisfactory [ ]; Fair [ ]; Poor [ ]; Variable [ ]

Best when _____

Worst when _____

Noticeable and persistent change in performance occurred _____ and was associated with _____

_____

Previous Reagents Used: a) Cationic _____ Anionic _____

b) Cationic _____ Anionic _____

c) Cationic _____ Anionic _____

d) Cationic _____ Anionic _____

Performance ranking (best to worst) _____

_____

_____

3. REAGENTS (Cont.)

Basis for selection and reasons for discontinuing:

a) _____

b) _____

c) _____

d) _____

4. PERFORMANCE REQUIREMENTS

Settling Rate: _____ minimum, _____ maximum

Overflow: Wedge clarity _____ minimum

Solids Content _____ maximum

Other _____

Underflow solids content: _____ minimum, _____ maximum

Other _____

Reagent: Cost _____ per _____ maximum

5. TEST OBJECTIVES:

_____

_____

_____

Reagent(s) of Specific Interest: _____

_____

_____

6. GENERAL

Nature and magnitude of effects of thickener performance on washery and/or associated operations with:

a) Best performance _____

b) Worst performance _____

Other Remarks: _____

_____

_____

_____

APPENDIX F - LABORATORY FLOCCULATION TESTS
LINE CREEK THICKENER FEED

LABORATORY FLOCCULATION TESTS

Subsequent to the field work, bench settling tests were performed with a view to future work planned for Line Creek. However, the information is also considered relevant to the field tests discussed in this report. The settling tests were carried out in 100 ml graduate cylinders using standard procedures on a sample of thickener feed. Reagent solutions were prepared using clean process water (pH 7.8) obtained from the washery. The feed sample contained 2.2% solids by weight, had a mean particle size of 42 μm and contained 66% minus 44 micron fines (Tables F-1 and F-2).

Four of the five reagents and combinations that were evaluated in the mobile plant plus an additional set involving the anionic Percol E10 (d) were tested. The anionic flocculant Crosfloc CFA 50 was not included. At least most of the cationics are known to be polyamine-based and of low molecular weight; all anionics are polyacrylamides of medium to high molecular weight with varying degrees of hydrolysis. At their optimum dosages, the cationics by themselves gave wedge readings that were on the average twice those obtained with the anionics by themselves. However, the settling rates were slower by a factor of more than 5. With the exception of the anionic d, neither the cationics nor the anionics used by themselves appeared capable of providing both adequate clarity and settling rate at the same time. With dual reagent addition, the cationic-anionic order gave approximately 1.3 times better clarity and twice the settling rate of the anionic-cationic addition order. However, the anionic-cationic order produced lower sediment volumes.

For the dual reagent results, the so-called "optimum" dosage was obtained on the basis of addition of the optimum dosage of the first reagent as determined from its single use, followed by incremental additions of the second reagent. As used in this table, therefore, the term "optimum" has a very restricted meaning, one which may or may not be accurate for the individual case. The ranking shown in the last column of the table is based on a performance factor (P), calculated from the unit cost at optimum dosage ($/t), settling rate (SR), wedge clarity (C) and sediment height (H):

$$P\ (\$/tph) = (\$/t) \cdot (1/SR) \cdot (46/C) \cdot (H)$$

The rankings confirm the general superiority of the cationic-anionic order as practiced at Line Creek and although they would not be entirely adequate by themselves, the anionics would be the best alternative if such were needed. On the basis of the rankings, the anionic Percol E10 (d) was superior to any other single reagent or combination. Similarly, the overall performances of anionic Percol 1011 (D) and cationic Alchem 8852 (B) could be expected to surpass that of the cationic-anionic combination E (Stockhausen). For cationic-anionic addition, the rankings show the relative order of effectiveness as reagent combination B, followed by D, d, C and E.

Table F-1 - Characteristics of Line Creek thickener products (1983)

Sample	Solids content (%)	pH
Feed	2.22	6.74
Underflow	33.06	6.75
Overflow	0.04	6.69
Process water	0.04	7.78

Table F-2 - Screen analysis of Line Creek thickener feed (1983)

Mesh	Weight (%)	Undersize (%)
+ 30	-	-
30 - 60	1.20	100.00
60 - 100	6.35	98.80
100 - 140	5.25	92.45
140 - 200	7.73	87.20
200 - 325	13.50	79.47
- 325	65.97	65.97
Total	100.00	

Table F-3 - Results of laboratory flocculation tests for Line Creek thickener feed (2.2% solids)

Reagent*		Optimum dosage (g/t)	Settling rate (cm/h)	Wedge clarity	Sediment height (cm)	Cost ($/t)	Rank
Cationic	B	72	652	35	8	0.122	7
	C	126	482	28	7	0.238	18
	D	90	430	21	8	0.179	19
	E	108	600	46	9	0.270	17
Anionic	B	54	3235	9	9	0.162	11
	C	54	3115	8	8	0.184	13
	D	90	3547	21	10	0.266	6
	d	90	3300	46	9	0.266	1
	E	36	2343	6	8	0.144	15
An-Cat	B	54 + 54	1273	35	8	0.254	9
	C	54 + 54	1516	22	8	0.286	14
	D	90 + 54	1418	25	8	0.373	16
	d	90 + 36	988	46	7	0.337	12
	E	36 + 90	1560	46	9	0.369	10
Cat-An	B	72 + 90	3278	46	10	0.392	2
	C	126 + 72	2720	46	9	0.483	5
	D	90 + 72	2772	46	9	0.392	3
	d	90 + 90	3388	46	10	0.445	4
	E	108 + 72	2145	46	8	0.558	8

*Designations as in Tables 3 to 6 in main body of report
d: Percol 1697 (cationic) + Percol E10 (anionic)